Article

Volume 25 (2026), pp. 259-278
American Journal of STEM Education: Issues and Perspectives
eISSN 30.3-1190| Print ISSN: 3069-0072
https://doi.org/10.32674/wt0f6y97

Mini-Cycle PBL: A Short-Cycle, Career-Connected Framework for Middle Grades STEM Education

Angela McDaniel
American College of Education, United States
Amcdani1@mail.wvu.edu

ABSTRACT

Middle grades STEM teachers, particularly in rural schools, often encounter structural constraints that limit sustained project-based learning (PBL). This descriptive case study introduces Mini-Cycle PBL, a five-day instructional framework that retains core PBL elements within time-limited classroom contexts. Grounded in experiential learning, constructivism, place-conscious pedagogy, and STEM identity theory, the model emphasizes iterative design, applied investigation, and local career relevance. Data were drawn from classroom observations, student artifacts, and embedded micro-assessments involving approximately 120 eighth-grade students across four rural STEM classes during a hydraulic prosthetic design challenge. Analysis indicates that students engaged in multiple cycles of testing and revision, demonstrated developing conceptual understanding of hydraulic force transfer, and articulated emerging connections to STEM careers. These findings suggest that short-cycle inquiry models may offer a feasible structure for supporting engineering engagement and identity development within rural instructional constraints.

Keywords: Design, Engineering, Mini-Cycle PBL, PBL, STEM education

INTRODUCTION

Rural STEM educators frequently navigate instructional conditions—such as limited laboratory resources, abbreviated class periods, staffing constraints, and rigid pacing guides—that complicate sustained implementation of project-based learning (PBL). Although extended PBL models have been associated with deeper conceptual understanding, increased engagement, and authentic disciplinary practice (Krajcik & Blumenfeld, 2006; Thomas, 2000), their enactment often requires flexible scheduling, access to materials, and institutional support that are unevenly distributed across rural contexts (Showalter et al., 2019). As a result, educators must frequently adapt ambitious instructional designs to settings with constrained time and resources.

Short-cycle inquiry models have emerged as one potential approach to preserving core PB[OC4.1]L features—such as sustained investigation, iterative design, and authentic problem framing—while increasing feasibility within limited instructional windows (Hmelo-Silver, 2004). However, scholarship examining compressed inquiry structures remains limited, particularly in rural middle-grade STEM environments. Furthermore, research on STEM identity development suggests that repeated opportunities for competence, recognition, and meaningful participation are central to students' long-term engagement in STEM pathways (Carlone & Johnson, 2007). The extent to which short-cycle models can support such identity development warrants further examination.

Mini-Cycle PBL is a five-day, career-connected instructional framework developed to address these intersecting concerns of feasibility, equity, and identity formation. In this manuscript, Mini-Cycle PBL refers specifically to the structured short-cycle model examined in this study. In contrast, broader terms such as "short-cycle inquiry" denote compressed investigation formats more generally. The purpose of this descriptive case study is to (a) articulate the theoretical foundations of the Mini-Cycle model, (b) illustrate its enactment during a rural middle-grade engineering design challenge, and (c) examine how a short-cycle structure may support accessible and context-responsive STEM engagement under typical rural instructional constraints.

The following question guided this descriptive case study: How does the Mini-Cycle PBL framework operate within a rural middle-grade STEM classroom, and what patterns of engagement and reasoning emerge within its compressed inquiry structure?

LITERATURE REVIEW

The literature informing this study spans four interconnected areas: project-based learning (PBL), short-cycle inquiry models, rural STEM education, and STEM identity development. Together, these areas highlight both the strengths and limitations of traditional PBL, particularly in rural settings where time, staffing, and material constraints influence instructional decisions. This body of research supports the need for an instructional model that is theoretically grounded while remaining practical and adaptable for rural middle-grade STEM classrooms.

Project-based learning is widely recognized for promoting deeper understanding through authentic investigation, collaboration, and iterative problem-solving (Condliffe et al., 2019; Krajcik & Merritt, 2023). Frameworks such as Gold Standard PBL emphasize authenticity, inquiry, student voice, revision, and public products as key design elements (PBLWorks, 2023). However, research consistently identifies barriers to implementation, including limited instructional time, assessment pressures, lack of planning time, insufficient materials, and limited teacher training (Condliffe et al., 2019; Krajcik & Merritt, 2023). These challenges are often intensified in rural schools, where educators face additional constraints such as staffing shortages and geographic isolation (Azano et al., 2020). As a result, many teachers struggle to sustain lengthy PBL experiences despite recognizing their instructional value.

Short-cycle and modular inquiry approaches offer a practical alternative that preserves many strengths of PBL while reducing time and material demands. Research suggests that compact design–test–refine cycles can maintain rigorous scientific and engineering practices while increasing feasibility in middle-grade classrooms (Strong et al., 2020). These shorter investigations provide students with frequent opportunities to revise ideas, learn from failure, and build confidence through visible progress (Krajcik & Merritt, 2023). Such approaches are particularly valuable in classrooms operating under strict pacing requirements.

Rural STEM education research further emphasizes the importance of instructional efficiency and local relevance. Rural schools often experience limited access to specialized staff, professional development, and laboratory resources (Barley & Beesley, 2007; Showalter et al., 2019). Place-based STEM approaches help address these challenges by connecting learning to local industries, environmental issues, and community experiences (Azano et al., 2020). Research shows that when STEM learning reflects authentic local contexts, students demonstrate stronger engagement and motivation (Westbrook, 2022). Short-cycle STEM experiences align well with these goals because they allow teachers to implement meaningful, locally grounded investigations without requiring extended instructional time or extensive equipment.

Research on STEM identity development also highlights the importance of repeated, authentic STEM experiences during the middle grades. Students who engage in iterative problem-solving and experience success in STEM activities are more likely to see themselves as capable participants in STEM fields (Tai et al., 2020; Vincent-Ruz & Schunn, 2018). For rural learners, these experiences are especially important because access to STEM role models and career pathways may be limited. Opportunities to engage in authentic, community-connected problem-solving can help students develop confidence, persistence, and a stronger sense of belonging within STEM disciplines.

Integrative Synthesis and Conceptual Gap

Although scholarship has independently established the benefits of extended project-based learning (PBL), short-cycle inquiry structures, rural STEM adaptation, and STEM identity development, these strands have rarely been examined in concert. Extended PBL models are consistently associated with deeper conceptual understanding, collaborative reasoning, and authentic disciplinary engagement (Krajcik & Blumenfeld, 2006; Thomas, 2000). However, these models often presume scheduling flexibility, material access, and institutional support that are unevenly distributed across rural contexts (Showalter et al., 2019). In contrast, short-cycle or modular inquiry approaches increase instructional feasibility by compressing investigation and design into manageable segments (Hmelo-Silver, 2004). However, existing research has primarily emphasized engagement and content learning rather than long-term identity development.

Rural STEM settings introduce additional structural and sociocultural considerations, including constrained professional networks and limited exposure to STEM career pathways (Azano & Stewart, 2015). At the same time, research on STEM identity suggests that competence, recognition, and meaningful participation are central to sustained engagement in STEM disciplines (Carlone & Johnson, 2007; Hazari et al., 2010). Identity development is shaped not only by performance but also by repeated opportunities for iterative participation within authentic communities of practice (Wenger, 1998). The intersection of these domains raises an unresolved question: Can compressed inquiry models meaningfully support both instructional feasibility and the development of STEM identity in rural middle-grade settings?

This gap suggests a need for theoretically grounded models that integrate experiential learning, place-conscious pedagogy, and identity theory within structures that remain realistic for time-constrained classrooms.

THEORETICAL FRAMEWORK

Mini-Cycle PBL is grounded in several overlapping theories that emphasize active learning, iteration, collaboration, and contextual relevance. Together, these perspectives help explain how short-cycle, career-connected STEM experiences can support student learning in rural settings where time, materials, and instructional support may be limited.

Experiential learning theory provides a central foundation. Kolb's (1984) learning cycle describes learning as an iterative process of experience, reflection, conceptualization, and re-engagement. Short-cycle STEM challenges align with this framework by giving students repeated opportunities to test ideas, reflect on outcomes, and refine their thinking within manageable instructional periods (Krajcik & Merritt, 2023).

Mini-Cycle PBL is also informed by constructionist and social constructivist theories, which emphasize learning through creating, collaboration, and dialogue. Hands-on engineering and design experiences allow students to externalize ideas, negotiate meaning with peers, and strengthen conceptual understanding through revision and testing (Reiser et al., 2021).

Place-conscious pedagogy further shapes the framework by emphasizing the importance of local context in learning. Research in rural education suggests that STEM experiences connected to community issues, regional industries, and local environments increase relevance and student engagement (Azano et al., 2020; Westbrook, 2022). Mini-Cycle PBL encourages teachers to situate investigations within familiar community contexts, even when instructional resources are limited.

The framework also draws on STEM identity theory, which highlights the importance of competence, belonging, and recognition in shaping long-term STEM engagement. Iterative design experiences that allow students to revise ideas, experience success, and receive feedback can strengthen confidence and support emerging STEM identities, particularly during the middle grades (Vincent-Ruz & Schunn, 2018; Tai et al., 2020). In rural settings, where access to STEM role models and opportunities may be uneven, these structured opportunities for participation and recognition become especially important.

Together, these theories support Mini-Cycle PBL as a model that combines instructional feasibility with opportunities for meaningful STEM participation. While short-cycle inquiry cannot replace long-term engagement, it can provide repeatable entry points into authentic STEM learning experiences within realistic classroom constraints.

RESEARCH METHOD

This study employed a descriptive case study design (Yin, 2018) to examine the effectiveness of the Mini-Cycle PBL framework within a naturalistic classroom context. A descriptive approach was selected because the study's purpose was not to evaluate causal effectiveness or compare models, but rather to document implementation processes and analyze how students engaged with a compressed inquiry structure under typical rural instructional constraints. Case study methodology is appropriate for examining context-dependent phenomena in which instructional design and environment are inseparable (Merriam & Tisdell, 2016). The study, therefore, emphasizes analytic description and theoretical interpretation rather than experimental comparison.

Instructional Context

Participants included approximately 120 eighth-grade students enrolled in five STEM classes at a rural middle school in the southeastern United States. Students ranged in age from 13 to 14 years. Classes were approximately 45% female and 55% male, with 75% receiving free or reduced lunch.[OC7.1] The school serves a predominantly rural population characterized by limited access to advanced STEM coursework and industry networks. Demographic characteristics reflected the broader community context, including socioeconomic diversity consistent with rural districts in the region. Participation in the instructional unit was embedded within regular classroom instruction; no students were excluded. Because the study focused on model implementation rather than subgroup comparisons, analysis was conducted at the classroom level rather than disaggregated by demographic variables.

Data Sources and Evidence

Data were collected across the five-day instructional cycle in each of the four classrooms. Sources included structured classroom observations, student design artifacts, engineering notebooks, and embedded micro-assessments administered at key phases of the cycle. Observations were conducted during active design and testing periods and documented using field notes aligned to the Mini-Cycle phases (problem framing, design planning, testing, revision, and presentation). Student artifacts included initial design sketches, revision plans, and final prototypes. Micro-assessments included short reflective prompts and exit slips designed to capture conceptual understanding and perceived relevance.

Analytic Approach

Data analysis followed an iterative analytic approach. Observation notes and student artifacts were reviewed multiple times to identify patterns aligned with the theoretical framework, including evidence of iterative reasoning, conceptual refinement, and identity-relevant language (e.g., references to career pathways or perceived competence). Rather than coding for statistical frequency, analysis emphasized thematic patterns across classrooms. Triangulation was achieved by examining consistency between observed behaviors, artifact revisions, and student reflections. Interpretations were informed by experiential learning theory and

STEM identity constructs, thereby grounding the analysis in established theoretical lenses.

Limitations

Several limitations should be acknowledged. First, the study employed a descriptive case study design without a comparison group; therefore, findings should not be interpreted as evidence of causal impact. Second, data were collected within a single rural school context, limiting generalizability. Third, identity development was inferred from student reflections and observable behaviors within a short instructional window; long-term identity outcomes were not measured. Finally, implementation was conducted within existing classroom structures, and variability in teacher facilitation may have influenced student experiences. Future research should explore longitudinal and comparative designs further to examine the developmental effects of short-cycle inquiry models.

Mini-Cycle PBL Model Representation

Figure 1 presents the Mini-Cycle PBL model used in this study. The infographic summarizes the core components of the short-cycle approach and illustrates how students progress through iterative phases of investigation, design, and reflection. The graphic provides a conceptual overview of the cycle and serves as the case example's organizational anchor.

Figure 1
MC PBL Infographic

Phases of the Mini-Cycle

Table 1 provides a detailed description of each phase of the Mini-Cycle PBL model. These descriptions guided the interpretation of classroom examples and illustrate how the components of short-cycle inquiry can be implemented within typical middle grades instructional constraints.

Mini-Cycle PBL is composed of the following phases:

1. Entry Event
2. Question Burst
3. Exploration
4. *Quick Feedback*
5. *Public Share-Out*
6. Reflection
7. Assessment
8. Career Spotlight

Each phase supports inquiry, iteration, and disciplinary reasoning within a compressed timeline. The model is flexible enough to support STEM immersion days, classroom lessons, and rapid-cycle engineering experiences.

Table 1

Mini-Cycle PBL Phases: Brief Description + Claw Lesson Examples

Mini-Cycle Phase	Brief Description	Hydraulic Claw Example
Entry Event	A short, high-interest hook that sparks curiosity and introduces the challenge.	Students see a modern prosthetic hand in action and learn that James Hanger's prosthetic innovation began in their own community.
Question Burst	Students rapidly generate questions—focusing on curiosity rather than correctness.	"How does the claw squeeze?" "What makes it open?" "How do hydraulics work?" "Did Hanger use something like this?"
Exploration	Students investigate key ideas through hands-on tasks, demos, readings, or data.	Students test syringes and tubing with water; explore hydraulic vs. pneumatic systems; model input/output force.
Reflection	Students pause to consider what they are learning and how their ideas are changing.	Students answer: "What did your prototype teach you?" and "What are you changing and why?"

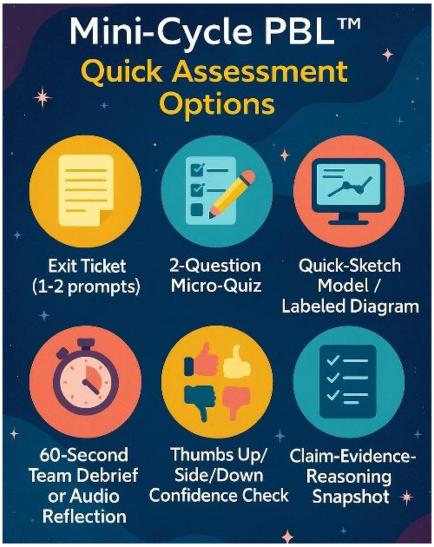
Assessment	A lightweight measure of understanding that captures core learning.	Two-question exit ticket: (1) "Describe how hydraulic pressure moves the claw." (2) "Describe one design improvement." (3) "What would you change with five more minutes?"
Career Spotlight	A short feature linking the Mini-Cycle to a real STEM career pathway.	Students connect the claw to biomedical engineering, prosthetics (Hanger), and local hydraulic and industrial maintenance jobs.

Assessment Within the Mini-Cycle

Although Mini-Cycle PBL is intentionally brief, assessment remains a critical driver of reflection, learning, and instructional adjustment within the 5–7-day arc. Formative checks are embedded lightly across phases so that teachers gain timely evidence of understanding without slowing momentum or adding heavy grading loads. Rather than multi-page rubrics or complete performance tasks, the model relies on rapid, high-signal assessments that surface misconceptions, confirm readiness for iteration, and prompt student metacognition—an approach consistent with research emphasizing focused, actionable feedback in inquiry-based environments (Krajcik & Merritt, 2023; Reiser et al., 2021).

Teachers can select from several quick options aligned to the day's learning target (shown in Figure 2): exit tickets with one or two focused prompts; two-question micro-quizzes administered orally, on paper, or digitally; quick-sketch models where students diagram and label a system; 60-second team debriefs or audio reflections; thumbs-up/side-down confidence gauges; or brief Claim-Evidence-Reasoning snapshots. These micro-assessments keep the cycle tight while still ensuring accountability, clarity, and visible learning progression.

Figure 2
Assessment Options



Importantly, the brevity of these assessments reinforces the iterative nature of the Mini-Cycle: evidence gathered each day informs immediate revision, supports productive struggle, and strengthens students' developing STEM identities by making progress visible through fast, achievable steps (Vincent-Ruz & Schunn, 2018; Tai et al., 2020).

CASE STUDY: PROSTHETIC DESIGN IN A POST–ZOMBIE APOCALYPSE SCENARIO

The Mini-Cycle PBL™ framework was implemented in four rural eighth-grade STEM classrooms (approximately 120 students) in which learners engaged in a 5–7-day hydraulic claw design challenge. The case illustrates how students progressed through the phases of the Mini-Cycle, how the structure supported iterative reasoning, and how locally relevant career connections strengthened engagement.

Engagement with the Entry Event and Question Burst

Students began the cycle by viewing a modern prosthetic hand in motion and learning about the historical significance of James Hanger, whose first prosthetic innovation originated in their own region. This local connection immediately anchored the challenge within a place-based context. During the Question Burst, students generated rapid questions that reflected curiosity rather than correctness—“How does the claw squeeze?” “What controls the force?” “Did Hanger use hydraulics?” Questions revealed early misconceptions but also strong interest, demonstrating the value of a compressed, high-energy launch.

Exploration and Early Conceptual Reasoning

During the Exploration phase, students investigated hydraulic force transfer using syringes, tubing, and water. Many initially believed the claw would “pull” rather than “push,” or that pressure would stay localized to the input syringe. Hands-on exploration allowed them to observe pressure transmission, air-water differences, and the relationship between input force and output movement. These early investigations aligned with experiential learning principles, giving students concrete experiences before formalizing their understanding.

Design, Testing, and Iteration Across Mini-Cycles

Students then designed simple hydraulic claws and engaged in two to three short cycles of testing and revision. Iterations were purposeful: students adjusted tubing length, syringe size, joint angles, and gripping surfaces. These revisions reflected constructionist principles as students externalized and refined their ideas through prototype building. Group discussions showed increasing use of disciplinary language—for example, shifting from “It’s too weak” to “The smaller syringe increases pressure, so it grips better.”

Career Connections and Relevance

Short career spotlights were embedded throughout the cycle, including biomedical engineering, prosthetics, industrial maintenance, and local hydraulics-based industries. These connections helped students view the task as more than a classroom exercise, supporting rural learners’ STEM identity development. Several students cited local companies or community members who work with hydraulic systems, indicating greater relevance.

Evidence of Conceptual Growth (Descriptive, Not Causal)

Quantitative data from brief exit slips suggested that many students developed stronger conceptual understanding during the cycle. Of the approximately 120 students, 84% correctly explained how fluid pressure transfers force after the task (compared to 21% on the pre-check), and 76% accurately predicted direction and magnitude of movement in different syringe configurations. These results are not used to claim causal impact; instead, they illustrate the types of conceptual reasoning students demonstrated during the Mini-Cycle experience.

Students' written explanations also became more precise across iterations. Early responses focused on surface features ("The claw doesn't open enough"). In contrast, later responses incorporated scientific reasoning ("When we switched to a smaller input syringe, the pressure increased, so the claw closed faster"). These descriptive patterns highlight how rapid cycles of build-test-revise can surface misconceptions and support refinement of ideas.

Summary of Case Insights

Taken together, the case shows that students were able to engage meaningfully in short-cycle inquiry, participate in multiple rounds of testing and revision, and articulate increasingly accurate explanations of hydraulic force transfer. These patterns are consistent with experiential and constructivist models of learning and illustrate how Mini-Cycle PBL™ can create accessible entry points into engineering design for rural middle-grade classrooms.

RESULTS

The results of this descriptive case illustrate how students engaged with the Mini-Cycle PBL framework across a five- to seven-day hydraulic claw investigation. Findings are presented in three areas aligned with the study's purpose: (1) patterns of student engagement across Mini-Cycle phases, (2) evidence of conceptual reasoning and iteration during hands-on design work, and (3) student explanations captured through brief, embedded assessments. Because this case study is illustrative rather than evaluative, the results describe student behaviors and observable patterns without attributing causal impact to the Mini-Cycle framework.

Student Engagement Across Mini-Cycle Phases

Students demonstrated consistent engagement throughout the Mini-Cycle, particularly during the Entry Event, Question Burst, and Exploration phases. The local historical connection to James Hanger sparked curiosity, and the Question Burst yielded a wide range of student-generated questions centered on hydraulic force, prosthetic movement, and mechanical control. These observations show that the short-cycle launch effectively supported curiosity and relevance, particularly for rural learners who recognized ties to local history and industry.

Patterns of Iteration and Design Thinking

Across the four classrooms (approximately 120 students), most student groups completed two to three iterations of their hydraulic claw prototype. Revisions primarily focused on adjusting tubing length, modifying syringes for increased pressure, altering joint angles, and improving grip surfaces. These iterative adjustments reflect students' developing understanding of hydraulic force transmission and their ability to translate conceptual reasoning into design decisions. Observational field notes documented a shift from trial-and-error approaches to more intentional troubleshooting as students progressed through the cycle.

Students increasingly used disciplinary language to justify their revisions. Early descriptions often referenced superficial features ("It won't open enough"), whereas later iterations included mechanistic explanations ("The smaller syringe creates higher pressure, so the claw needs less travel distance"). These patterns correspond with experiential and constructivist learning theories, indicating that hands-on iteration helped students refine and externalize their reasoning over time. The multiple cycles of testing and revision observed across classrooms illustrate how compressed inquiry structures can preserve the core iterative features of extended PBL. While the duration was limited, the repetition of design-feedback-revision sequences appears to have supported deeper reasoning within a constrained timeframe. This suggests that instructional compression does not necessarily eliminate opportunities for meaningful iteration when design phases are intentionally structured.

Conceptual Reasoning Demonstrated Through Embedded Assessment

Exit-slip data provided additional descriptive insight into students' understanding of hydraulic force transfer.
In your own words, explain how fluid pressure transfers force in a hydraulic system.

Look at the syringe system below. If the small syringe is pushed down 2 cm, what will happen to the larger syringe? Explain why.

Circle the best answer:
A. The fluid only moves in one direction
B. The pressure stays only in the first syringe
C. The pressure transfers through the fluid to other connected syringes
D. The fluid disappears

What was one thing you learned today about hydraulic systems?

Of the approximately 120 participating students, 84% correctly described how fluid pressure transfers force, compared to 21% on the pre-check. Similarly, 76% accurately predicted the direction and magnitude of movement resulting from paired syringe configurations. These results illustrate the kinds of explanations students were able to provide by the end of the Mini-Cycle experience; however, they are not used to infer causal changes in student learning. Responses were scored using a simple teacher-created rubric for conceptual accuracy.

2 = Accurate explanation/prediction
1 = Partially accurate explanation
0 = Inaccurate or missing response

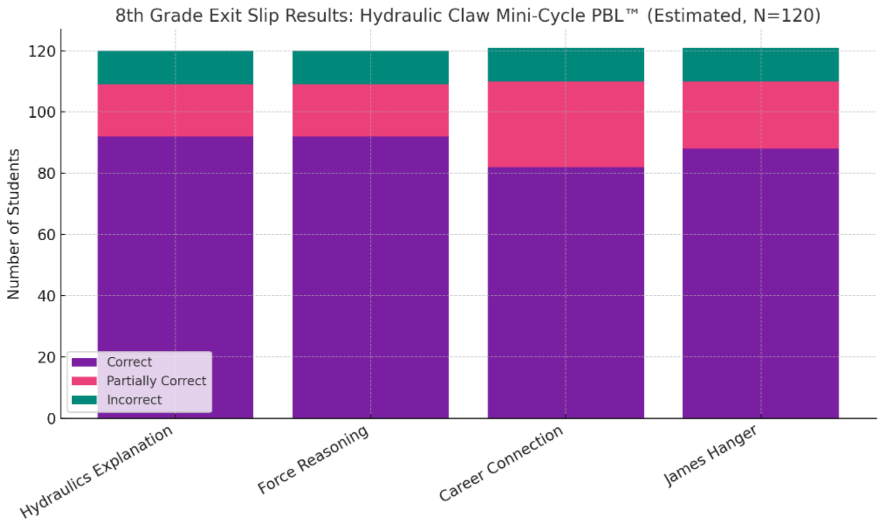
Qualitative analysis of student explanations showed similar patterns of growth. Initial responses typically relied on informal language ("It pushes a little"). In contrast, later responses integrated more precise descriptions ("When pressure increases in the input syringe, the force is distributed through the fluid and transferred to the output syringe, causing the claw to close"). Students also provided more detailed accounts of their design revisions, referencing pressure, stability, or mechanical leverage rather than surface-level modifications.

These patterns suggest that students were not merely constructing prototypes but engaging in iterative reasoning consistent with experiential learning theory. The observed shift from initial surface-level modifications to mechanistic adjustments indicates emerging conceptual integration rather than trial-and-error behavior. This progression aligns with constructivist accounts of learning in which conceptual refinement occurs through structured cycles of feedback and revision.

Summary of Results

Together, these findings illustrate how students engaged with the compressed inquiry structure of the Mini-Cycle model, participated in multiple rounds of purposeful iteration, and articulated increasingly accurate explanations of hydraulic force transfer. These descriptive patterns align with the theoretical foundations of experiential learning, constructivism, place-conscious STEM education, and STEM identity development, supporting the paper's purpose of demonstrating how short-cycle PBL can operate effectively within rural middle-grade STEM classrooms.

Table 2
8th Grade Exit Slip Results



DISCUSSION

The findings should be interpreted within the theoretical and contextual boundaries of the study. Rather than evaluating the superiority of short-cycle inquiry over extended PBL, this study illustrates how a compressed design may preserve essential elements of iterative reasoning and contextual relevance in settings where extended models are difficult to sustain. The results contribute to ongoing conversations about how structural feasibility and developmental opportunity intersect in rural STEM education.

The purpose of this descriptive case study was to illustrate how the Mini-Cycle PBL model operates within rural middle-grade STEM classrooms and to examine the kinds of student engagement and reasoning that emerge within its short-cycle structure. Although the model draws from established project-based learning principles, its design intentionally compresses core elements of inquiry and iteration into a format that is feasible within the instructional conditions common to rural schools. The findings from this case provide insight into how a short but tightly structured sequence can support engagement, conceptual reasoning, and local relevance for learners.

Mini-Cycle PBL as a Pragmatic Adaptation of Project-Based Learning

Mini-Cycle PBL is not intended to serve as a replacement for extended project-based learning. Instead, it is a practical adaptation that preserves essential design components—such as inquiry, modeling, iteration, critique, and career-connected reflection—within a five- to seven-day arc. By distilling these elements into a shorter format, the model responds to constraints such as limited class time, pacing pressures, and variable access to materials. This pragmatic flexibility is essential in rural schools, where teachers often navigate tight schedules and resource limitations while still striving to provide meaningful STEM experiences. From a theoretical standpoint, the Mini-Cycle framework can be understood as a structural adaptation that maintains alignment with experiential learning and identity development constructs while operating within constrained instructional schedules. By compressing, rather than eliminating, iterative engagement, the model creates repeated micro-opportunities for competence demonstration and recognition. However, identity development remains cumulative and socially mediated; therefore, short-cycle inquiry should be viewed as a contributory component within broader instructional sequences rather than a standalone solution.

Insights Into Iteration, Engagement, and Conceptual Reasoning

Across approximately 120 eighth-grade students, the Mini-Cycle created repeated opportunities for iteration and revision during the hydraulic claw challenge. Students engaged in two to three rounds of purposeful design adjustments, moving from trial-and-error approaches to more intentional modifications informed by their emerging understanding of hydraulic force transfer. These behaviors are consistent with experiential and constructivist perspectives, which emphasize learning through cycles of action, reflection, conceptualization, and re-engagement.

As students refined their prototypes, their explanations also became increasingly mechanistic. Later responses demonstrated more precise descriptions of pressure transfer, syringe size effects, and force distribution. These patterns suggest that, even within abbreviated timeframes, iterative, hands-on work can prompt learners to articulate and refine their disciplinary reasoning.

Relevance Through Local and Career Connections

Short career spotlights embedded throughout the cycle helped situate the investigation within a context familiar to rural learners. Students drew connections between hydraulic systems, regional industries, and the historical legacy of James Hanger, whose early prosthetic work began in their geographic region. These

place-conscious elements supported relevance and engagement by linking classroom engineering tasks to local narratives and workforce pathways. For students with limited exposure to STEM careers, these small but frequent connections can help make engineering roles more visible and attainable.
Students' references to local engineering and technical professions indicate that contextualized framing may strengthen perceived relevance, a key component of place-conscious pedagogy. Although the study did not measure long-term career intent, the integration of regional workforce examples appeared to support situational recognition and the use of emerging identity language.

Interpretive Boundaries

The descriptive nature of this case means that findings are not intended to imply causal learning effects. Increases in explanatory detail on exit slips illustrate the kinds of reasoning students demonstrated within the Mini-Cycle experience rather than the degree to which the model directly produced conceptual change. One student commented, "Before this, I didn't really get how hydraulics worked. I thought the water just pushed things randomly, but after we tested different syringe sizes, I saw that the pressure transfers through the fluid and changes how much force you get." Other instructional structures involving hands-on exploration and targeted discussion could yield similar improvements. The value of the Mini-Cycle, as shown in this case, lies in its ability to create rapid, structured opportunities for investigation and revision within realistic classroom constraints. By situating short-cycle inquiry within an identity-aware rural framework, this study contributes to scholarship on CTE and STEM instructional design by articulating how structural feasibility and developmental engagement may coexist within constrained educational environments.

Implications for Rural STEM Instruction

This case highlights several practical considerations for teachers seeking to incorporate authentic engineering design into constrained instructional environments. The short-cycle structure may offer an accessible entry point for hands-on STEM learning, enabling teachers to implement inquiry-oriented design experiences without sacrificing pacing or logistical feasibility. The integrated career connections provide additional value, particularly for rural learners who benefit from explicit visibility into local STEM applications and pathways. The Mini-Cycle's emphasis on rapid feedback and daily evidence of learning also aligns well with formative assessment approaches that support identity development and student confidence.

CONCLUSIONS

This study demonstrates that Mini-Cycle PBL can provide meaningful, authentic STEM learning experiences within the compressed timelines common in middle-grade classrooms. Through the hydraulic prosthetic challenge, students developed conceptual understanding of hydraulics, engaged in sustained iterative design, and strengthened their awareness of STEM pathways—all within a five-day instructional arc. The model's design-test-refine structure, coupled with place-based elements tied to West Virginia's engineering history, created an experience that was both engaging and instructionally effective.

The results highlight the potential of short-cycle PBL to address two persistent challenges in rural STEM education: limited instructional time and uneven access to materials. By focusing on rapid iteration, embedded micro-assessment, and contextual relevance, Mini-Cycle PBL offers a practical approach for teachers seeking to implement hands-on learning without sacrificing pacing or feasibility. For students, these short, intense cycles create identity-building moments that help them see themselves as problem solvers and emerging engineers.

Future work may explore additional case examples, cross-disciplinary applications, or teacher perceptions of the model's usability in different rural contexts. However, even within the scope of this single case, the findings suggest that short-cycle PBL represents a promising pathway for expanding equitable access to STEM learning—one that honors the realities of rural classrooms while preserving the depth, rigor, and authenticity of engineering education.

As STEM reform efforts continue to emphasize authenticity and engineering integration, instructional structures that balance rigor with feasibility are essential. Mini-Cycle PBL offers a model for maintaining iterative design within constrained settings, expanding access to meaningful engineering participation without requiring extended instructional blocks.

ACKNOWLEDGMENT

The author used OpenAI's ChatGPT or AI tools to edit this manuscript for grammar and graphics. All content was generated solely by the author.

REFERENCES

Azano, A. P., Callahan, C. M., Brodersen, A. V., & Caughey, M. (2020). *Rural gifted education: A research-based resource*. Routledge.

Azano, A. P., & Stewart, T. T. (2015). Exploring place and practicing justice: Preparing pre-service teachers for success in rural schools. *Journal of Research in Rural Education, 30*(9), 1–12. https://eric.ed.gov/?id=EJ1064099

Barley, Z. A., & Beesley, A. D. (2007). Rural school success: What can we learn? *Journal of Research in Rural Education, 22*(1), 1–16. https://jrre.psu.edu/sites/default/files/2019-08/22-1.pdf
Bogdan, R. C., & Biklen, S. K. (2007). *Qualitative research for education: An introduction to theories and methods* (5th ed.). Pearson.
Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187–1218. https://doi.org/10.1002/tea.20237
Condliffe, B., Quint, J., Visher, M. G., Dhar, D., Boccanfuso, C., & Nelson, E. (2017). Project-based learning: A literature review. *MDRC*. https://eric.ed.gov/?id=ED578933
Dou, R., & Cian, H. (2022). Development and validation of the STEM Identity Scale. *Journal of Research in Science Teaching, 59*(6), 889–915. https://doi.org/10.1002/tea.21745
Hazari, Z., Sonnert, G., Sadler, P., & Shanahan, M. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice. *Journal of Research in Science Teaching, 47*(8), 978–1003. https://doi.org/10.1002/tea.20363
Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3
Krajcik, J. (2015). Supporting three-dimensional teaching and learning through project-based learning. *Science and Children, 53*(3), 6–8.
Krajcik, J. S., & Blumenfeld, P. C. (2006). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 317–334). Cambridge University Press.
Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.
PBLWorks. (2023). *Gold standard PBL: Project design elements*. https://www.pblworks.org/what-is-pbl/gold-standard-project-design
Reiser, B. J., Novak, M., McGill, T. A. W., Horn, B. R., & Chen, J. (2021). Mapping the design of project-based science learning environments to learning and teaching goals. *Journal of the Learning Sciences, 30*(1), 131–175. https://doi.org/10.1080/10508406.2020.1810237
Showalter, D., Haran, S. L., Johnson, J., & Klein, R. (2019). *Why rural matters 2018–2019: The time is now*. Rural School and Community Trust.
Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*(5777), 1143–1144. https://doi.org/10.1126/science.1128690
Thomas, J. W. (2000). *A review of research on project-based learning*. Autodesk Foundation.

https://my.pblworks.org/resource/document/a_review_of_research_on_project_based_learninghttps://my.pblworks.org/resource/document/a_review_of_research_on_project_based_learning

Vincent-Ruz, P., & Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *International Journal of STEM Education, 5*(1), Article 48. https://doi.org/10.1186/s40594-018-0140-5

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

Westbrook, E. (2022). STEMulating interest with a rural place-conscious curriculum. *Theory & Practice in Rural Education, 12*(2), 197–220. https://doi.org/10.3776/tpre.2022.v12n2p197-220

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage.

Bio

ANGELA MCDANIEL, EdD, is an Adjunct Professor in STEM at the American College of Education, as well as Director of Curriculum and Professional Development at the STEAM Technical Assistance Center at West Virginia University. Email: angela.mcdaniel@ace.edu