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Article

The Reconstruction of Project-Based Curriculum Guided by Core Literacy: Design and Effectiveness in Promoting Deep Learning in Students

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Abstract: Global educational reforms increasingly prioritize core competencies, with Project-Based Learning (PBL) as a key strategy for fostering transferable, deeper learning. However, a gap remains between PBL advocacy and implementation, as projects are often seen as isolated tasks rather than integral to curriculum redesign for systemic competency development. Current research insufficiently examines how PBL can systematically serve as the core structure for curriculum reconstruction to foster core literacy and deep learning. The mechanisms and outcomes of this approach remain underexplored. This study used design-based research to implement the Core Literacy-Embedded Project Cycle (CLPC) model in an 8th-grade biology unit. A mixed-methods approach compared an intervention group (n=60) with a comparison group (n=60), using pre-post tests, scenario-based tasks, project analysis, classroom observations, and reflective journals. The reconstructed curriculum led to equivalent gains in foundational knowledge but significantly better performance in knowledge transfer and application for the intervention group. Qualitative data showed increases in metacognitive engagement, reasoning, and collaboration, alongside challenges in time allocation and teacher facilitation. This study provides the validated CLPC model, demonstrating that integrating core literacy and PBL promotes deep learning without sacrificing content mastery. It offers practical insights for educators and suggests future research into cross-disciplinary applications and long-term impact studies.

Keywords: Core literacy; Project-Based Learning (PBL); Deep learning; Curriculum design; Educational outcomes

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1. Introduction

The global shift in educational paradigms from content-centric instruction toward the cultivation of core competencies, such as critical thinking, collaboration, and creative problem-solving, represents a fundamental response to the complexities of the 21st century [1, 2]. Within this landscape, Project-Based Learning (PBL) has emerged as a leading pedagogical strategy, celebrated for its capacity to engage students in authentic inquiry and active knowledge construction [3]. Concurrently, the concept of deep learning, characterized by the integration, critical examination, and transfer of knowledge to novel situations, has gained prominence as the desired cognitive outcome of meaningful education. In theory, these three elements form a powerful synergy: core literacy defines the essential competencies, PBL provides an experiential vehicle for their development, and deep learning constitutes the resulting cognitive state [4]. This alignment positions PBL as a promising pathway to achieving overarching educational reform goals.

However, a critical disjunction persists between this theoretical promise and widespread classroom reality. Prevailing research and practice often treat PBL as a discrete instructional activity, a stimulating supplement to an otherwise conventional curriculum. Consequently, studies frequently investigate the impact of isolated, short-term projects on specific engagement or content retention metrics [5]. This approach leaves a significant gap in understanding: the systemic integration of PBL as an organizing principle for curriculum reconstruction. Little is known about how entire curricular units can be fundamentally redesigned, or reconstructed, with core literacy as the central design driver and PBL as the sustained pedagogical engine, nor about the specific effects such reconstruction has on fostering the processes and outcomes of deep learning [6]. This gap is pivotal, as it addresses not merely how to do a project, but how to redesign learning pathways to make deep, competency-driven learning the consistent norm rather than the occasional exception.

This study, therefore, seeks to bridge this gap by investigating the following central question: How can a subject-specific curriculum be reconstructed around core literacy through a project-based framework, and what impact does this reconstruction have on students' deep learning processes and outcomes? The innovation of this research lies in its focus on curriculum reconstruction as both the intervention and the unit of analysis, moving beyond PBL as a method to examine it as a structural framework for curricular redesign.

To address this question, the research employs a design-based research (DBR) methodology conducted within a real-world secondary school context. Focusing on an 8th-grade biology unit, the study involved the iterative design, implementation, and evaluation of a reconstructed curriculum, the Core Literacy-Embedded Project Cycle (CLPC) model, compared against a traditional instruction control group. A mixed-methods approach was utilized, combining quantitative measures (pre-/post-tests of conceptual understanding and knowledge transfer) with qualitative data (classroom observations, student journals, artifact analysis, and teacher interviews) to capture both the outcomes and the lived experiences of the intervention.

The significance of this work is twofold. Theoretically, it contributes a testable model (CLPC) that explicitly links curriculum theory, competency frameworks, and the learning sciences, offering a new lens for conceptualizing competency-based curriculum design. Practically, it provides educators and curriculum developers with empirically grounded insights into the design principles, implementation challenges, and tangible impacts of undertaking such a reconstruction, thereby offering a roadmap for translating policy-level calls for core literacy into actionable, classroom-level change that genuinely promotes deep learning

2. Literature Review

2.1 Core Literacy and Its Impact on Learning

Core literacy is vital for preparing students to face real-world challenges, emphasizing critical thinking, communication, and problem-solving. Research has shown that students with strong core literacy are better equipped to handle complex tasks, leading to improved academic performance, especially in tasks requiring deep understanding and application of knowledge [7, 8]. These competencies are crucial for adapting to the rapidly changing demands of society. However, applying core literacy in education remains challenging. Traditional curricula often prioritize rote memorization, failing to foster the integrated problem-solving skills essential for core literacy [9]. Moreover, assessing core literacy within conventional evaluation systems remains difficult, often leading to fragmented and superficial learning experiences.

Recent literature suggests that core literacy, traditionally viewed as isolated skills, must be contextualized or integrated across disciplines to enhance its applicability. Scholars have called for "situational" or "cross-disciplinary integration" of core literacy, yet there remains a lack of concrete curriculum models that operationalize this integration. This call aligns with East Asian curriculum reforms that position PBL as a key vehicle for cross-disciplinary core competencies. For example, Taiwan's 12-Year Curriculum emphasizes life-connected, self-directed learning, ideally realized through sustained PBL [10]. Similarly, STEAM-PBL fosters scientific inquiry alongside social responsibility and collaboration, central to 21st-century literacy [11]. This study addresses this gap by embedding core literacy within project-based curricula, offering a cohesive approach to supporting deep learning across various contexts.

2.2 PBL in Education

PBL is widely recognized for enhancing student engagement, critical thinking, and creativity by immersing students in real-world problems. This approach fosters deeper learning through inquiry-based activities, enabling students to apply knowledge in practical contexts. While PBL has demonstrated effectiveness in promoting motivation and making learning more relevant, its implementation presents challenges, particularly in resource-limited environments. PBL requires significant time, materials, and teacher expertise, which may be difficult for many schools to provide. Additionally, PBL often lacks scalability due to the necessary changes in traditional teaching methods and curriculum structures that many educational systems find difficult to adopt [12].

The existing body of research largely focuses on the effectiveness of PBL in individual projects. However, fewer studies explore PBL as the central organizing principle for curriculum design. While Understanding by Design emphasizes integration, it does not place PBL as a core, cyclical structure for the curriculum. This study aims to fill that gap by exploring how PBL can be integrated into curriculum design, systematically promoting core literacy and deep learning across multiple subjects. To address scalability, recent studies propose structured frameworks like the "Know-Need-Do" (KND) cycle, which helps teachers embed PBL systematically, aligning driving questions, disciplinary knowledge, and real-world action, turning it from an occasional activity into a curricular core [13].

2.3 Deep Learning and Its Role in Student Achievement

Deep learning is characterized by long-term retention and the ability to apply knowledge in complex, real-world situations. Research indicates that deep learning enhances critical thinking and problem-solving, better preparing students for challenges beyond the classroom [14]. Unlike surface learning, which emphasizes memorization, deep learning leads to better cognitive outcomes and deeper understanding. It equips students to navigate complex problems by engaging them in meaningful application of knowledge.

However, deep learning is difficult to assess using traditional testing methods, which often focus on rote recall rather than knowledge application [15]. Furthermore, fostering deep learning requires substantial changes in teaching practices and curriculum design, shifts that many educational systems struggle to implement [16]. For instance, conventional lesson structures rarely allocate sufficient time for collaborative inquiry or reflective synthesis, both of which are essential for deep cognitive engagement. Recent pedagogical innovations attempt to address this by reorganizing instructional time: flipped classroom models, for example, shift content delivery to pre-class settings and reserve face-to-face sessions for high-level tasks such as problem-solving, peer critique, and metacognitive reflection, conditions shown to significantly enhance deep learning [17]

As a result, deep learning remains underrepresented in traditional educational frameworks. Unlike surface learning, which may provide short-term academic success, deep learning promotes critical thinking and long-term retention. This paper addresses the gap in research by examining how project-based curricula, aligned with core literacy, can systematically promote deep learning across various subjects. Moreover, current assessments primarily focus on "outcomes" and neglect process data, such as metacognitive logs and collaborative discourse analysis, which are essential to understanding the mechanisms of deep learning. This study's mixed-methods design aims to fill this gap by incorporating both outcome-oriented and process-oriented data.

2.4 Summary of Literature and Conceptual Framework

The review of core literacy, PBL, and deep learning underscores the importance of integrating these concepts into a cohesive curriculum framework. Core literacy provides essential cognitive and social skills, while PBL offers a student-centered approach to learning. Deep learning promotes the retention and application of knowledge. However, the integration of these elements into comprehensive curricula remains underexplored. This paper proposes a new model that integrates core literacy and PBL into a unified curriculum framework, addressing the gaps in current educational approaches. Successful implementation of such an integrated framework also depends on teacher capacity. Studies show that when pre-service teachers engage in PBL-based curriculum design, they develop stronger interdisciplinary thinking and problem-solving confidence, yet many express anxiety about managing open-ended, student-driven classrooms [18]. This highlights the need for parallel investment in teacher professional development alongside curricular innovation. A conceptual diagram will illustrate the shift from traditional models to a more integrated approach that fosters deeper, more meaningful learning.

3. Theoretical Framework and Methodology

3.1 Theoretical Framework: "Core Literacy Anchored - Project Cycle" Curriculum Design Model

This study is grounded in an integrated theoretical framework that moves beyond the mere juxtaposition of established theories to propose a novel curriculum design model: the Core Literacy-Embedded Project Cycle (CLPC). This model posits that sustainable deep learning is best achieved not by adding projects to a traditional curriculum, but by fundamentally restructuring the curriculum around a recursive, literacy-driven project cycle. It synthesizes and operationalizes key tenets from Constructivist Learning Theory (emphasizing knowledge construction), the higher-order cognitive processes of Bloom's Taxonomy (emphasizing analysis and creation), and Socio-cultural Theory (emphasizing collaborative meaning-making). The CLPC model is visually represented in Figure 1 and functions as a dynamic, non-linear system for curriculum design and enactment.

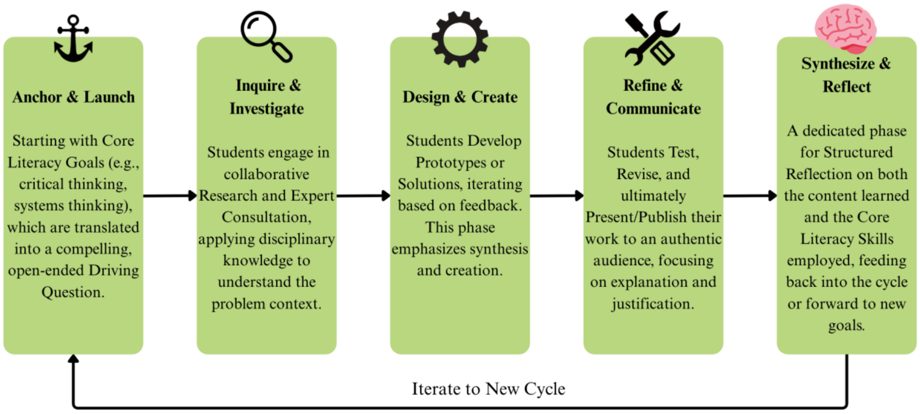

Figure 1. The Core Literacy-Embedded Project Cycle (CLPC) Model

This model constitutes a reconstruction of the traditional linear curriculum (often characterized by "Identify Objectives → Deliver Content → Assess via Test"). It replaces passive knowledge reception with active knowledge application, transforms assessment from an endpoint into a continuous feedback mechanism, and makes the development of core literacy the explicit and persistent driver of all instructional activities, rather than an implicit or occasional byproduct.

3.2 Research Methodology: Design-Based Experiment, Case Study, and Performance Analysis

This research employs a DBR methodology, chosen for its emphasis on developing theory through iterative design, implementation, and analysis in real-world educational settings. The study is structured as an intensive, longitudinal instrumental case study.

The study was conducted at a large public middle school in Shanghai, China, recognized for its engagement in pedagogical innovation. The research focused on the 8th-grade Biology course. The unit selected for reconstruction was "Ecosystems, Biodiversity, and Sustainable Development," a 12-week unit that traditionally combined textbook study, teacher-led experiments, and a final exam.

Four intact 8th-grade classes were involved (total N=120 students). Using a quasi-experimental design, two classes (n=60) were assigned as the intervention group, experiencing the curriculum as restructured by the CLPC model. The central driving question was: "How can we, as urban ecosystem consultants, design a viable plan to enhance local biodiversity and sustainability in our school community?" The other two classes (n=60) served as the comparison group, receiving instruction on the same core biological concepts through the school's standard, high-quality teaching methods of interactive lectures, guided lab work, and problem sets.

3.3 Data Collection and Analysis Methods

3.3.1 Data Collection Methods

Curriculum Artifacts & Design Logs: All lesson plans, project guides, and scaffolding materials for the reconstructed unit were collected. The researcher's log documented design rationale and adjustments made across two implementation cycles.

Pre- and Post-Assessments:

Conceptual Understanding Test: A standardized test measuring mastery of key biological concepts (e.g., energy flow, interdependence).

Scenario-Based Transfer Task: An open-ended written assessment presenting a novel environmental problem, evaluating students' ability to analyze, propose solutions, and justify reasoning.

Process-Oriented Data:

Structured Classroom Observations: Over 30 hours of observation were conducted using a protocol focusing on student discourse (e.g., frequency of explanatory and questioning talk), collaborative dynamics, and observable use of core literacy practices.

Student Project Journals: Collected weekly, these provided longitudinal data on individual thinking, problem-solving processes, and metacognitive reflections.

Focus Group Interviews: Conducted at the mid-point and end of the unit with a stratified sample of 16 intervention-group students to explore their perceptions of challenge, collaboration, and learning.

Outcome-Oriented Data:

Final Project Artifacts & Presentations: The comprehensive "Consultancy Report" and final presentation videos were collected as summative performance evidence.

Teacher Post-Implementation Interviews: Semi-structured interviews with the two participating biology teachers explored their insights on implementation challenges and observed student growth.

A summary of the data collection methods and their corresponding analysis techniques is provided in Table 1. This table outlines the data collection methods, their descriptions, and the analysis methods used to assess the collected data.

Table 1. Alignment of Data Sources with Research Focus

Research Focus	Primary Data Sources	Purpose & Analysis Link
Fidelity & Nature of Implementation	Curriculum Artifacts, Design Logs, Observation Notes, Teacher Interviews	To describe the curriculum reconstruction in practice and identify key enactments. Thematic analysis.

Cognitive & Knowledge Outcomes	Conceptual Tests (Quant), Transfer Tasks (Qual/Quant), Project Artifacts	To measure gains in content knowledge and application/transfer. Paired t-tests; rubric-based scoring.
Development of Core Literacy & Deep Learning Processes	Observation Notes, Student Journals, Focus Groups, Presentation Videos	To trace the development of critical thinking, collaboration, and metacognition. Thematic and discourse analysis; behavioral coding of presentations.
Research Focus	Primary Data Sources	Purpose & Analysis Link

3.3.2 Analysis Methods

Analysis occurred in two iterative strands:

1. Quantitative Analysis: Scores from the Conceptual Understanding Test were analyzed using paired-sample t-tests (within groups) and analysis of covariance (ANCOVA, between groups, with pre-test as covariate) to identify significant differences in knowledge gain. The Transfer Tasks were scored using a validated rubric, and scores were analyzed similarly.
2. Qualitative Analysis: All textual and visual data (journals, interviews, observations, artifacts) underwent systematic thematic analysis using NVivo software. An initial coding scheme was derived from the CLPC framework and core literacy dimensions, then refined inductively. Presentation videos were analyzed for evidence of communication and reasoning skills using a structured coding protocol. Methodological triangulation across data sources was used to establish the credibility and depth of findings.

This integrated methodological approach ensures that the study not only tests the efficacy of the CLPC model but also richly describes its enactment, providing actionable insights for theory and practice.

4. Findings and Discussion

4.1 Research Findings

4.1.1 Enactment and Challenges of Curriculum Reconstruction

The implementation of the CLPC model in the "Ecosystems" unit revealed a distinct shift in classroom dynamics, characterized by both transformative practices and significant logistical and pedagogical challenges, as documented through classroom observations and teacher interviews.

Enacted Practices: The classroom evolved from a teacher-centered space into a collaborative workshop. The driving question, "How can we, as urban ecosystem consultants, design a viable plan to enhance local biodiversity?" served as a persistent organizational anchor. For instance, students conducted biodiversity audits of the school grounds, requiring them to apply taxonomic knowledge (e.g., identifying local plant species) and data collection skills not as ends in themselves, but as evidence for their consultancy reports. Teacher-led lectures were replaced by "expert briefings," where teachers provided just-in-time mini-lessons on concepts like nitrogen cycles when students needed that knowledge to assess the feasibility of their proposed composting solutions. A significant portion of class time was dedicated to team "consultancy meetings" for planning, peer critique, and iterative revision of their proposals, observed to foster sustained, task-focused discourse.

Key Challenges: The reconstruction encountered three primary obstacles. First, temporal tension was acute. Teachers reported that the open-ended inquiry phase consumed more time than anticipated, compressing the later refinement stages. This often conflicted with the fixed schedule of the broader school curriculum. Second, teacher role re-conception proved demanding. As one teacher noted, "The hardest part was resisting the urge to give them the 'right' answer when they were struggling. I had to learn to ask more probing questions rather than provide solutions." This shift from content deliverer to facilitator and coach required ongoing support and reflection. Third, assessment alignment posed difficulties. Integrating formative, competency-focused assessment (e.g., evaluating the quality of team collaboration or the logic of an argument within a draft proposal) within the existing school framework that prioritized standardized test scores created a persistent sense of dissonance for both teachers and students.

4.1.2 Evidentiary Patterns of Student Deep Learning

Analysis of multi-source data revealed concrete patterns indicative of deep learning among students in the intervention group, contrasting with the performance of the comparison group.

Conceptual Understanding and Transfer: On the post-intervention conceptual understanding test, ANCOVA results (controlling for pre-test scores) showed no statistically significant difference between the intervention (M=82.4, SD=6.7) and comparison groups (M=80.1, SD=7.9), F(1, 117)=2.15, p=.145. Both groups mastered the core biological facts. However, on the novel Scenario-Based Transfer Task, the intervention group significantly outperformed the comparison group (Intervention M=4.2/6, SD=0.8; Comparison M=2.9/6, SD=1.1; F(1,117)=45.32, p<.001, $\eta p2$=.28). Rubric analysis showed intervention group students were 60% more likely to propose multi-faceted solutions (e.g., combining habitat creation with community education) rather than single-action responses.

Cognitive and Metacognitive Processes: Thematic analysis of student project journals showed a marked evolution. In the first two weeks, only 18% of journal entries contained explicit metacognitive statements (e.g., "I'm not sure how to connect food webs to our school garden idea"). By the project's final two weeks, this proportion rose to 52%, with entries like, "Our initial model failed because we didn't account for seasonal changes. We need to revise our data collection plan." This indicates a shift towards self-regulated learning. Furthermore, coding of final presentation videos revealed that intervention group students used causal and systems-based reasoning (e.g., "If we introduce native plants, then we should see an increase in pollinators, which would affect...") at a rate three times higher than their peers in the comparison group presentations, who primarily engaged in descriptive reporting of findings.

Collaborative Knowledge Building: Classroom observation data quantified a shift in discourse patterns. In early-stage team meetings, over 70% of student talk was managerial ("You do this part"). In final-stage meetings, explanatory and integrative talk ("I think that idea works because it aligns with the principle of energy efficiency we learned about") dominated, accounting for over 65% of exchanges. This suggests a move towards collaboration focused on collective sense-making rather than task division.

To provide a consolidated overview of the key empirical findings, Table 2 summarizes the evidence of deep learning across multiple dimensions, contrasting the intervention and comparison groups.

Table 2. Summary of Key Findings on Deep Learning Outcomes

Assessment Dimension	Key Finding (Intervention Group)	Comparison Group / Benchmark
Knowledge Transfer & Application	Significantly higher score on transfer task (M=4.2/6). 60% more likely to propose integrative solutions.	Significantly lower score (M=2.9/6). Solutions were predominantly singular.
Conceptual Mastery	Equivalent mastery of core concepts (M=82.4).	Equivalent mastery (M=80.1). No significant difference.

Metacognitive Engagement	Metacognitive statements in journals increased from 18% to 52% of entries.	Not comparably measured. Highlights process-specific growth.
Quality of Reasoning	Used causal/systems reasoning in presentations at 3x the rate observed in comparison baseline.	Discourse was primarily descriptive, with minimal causal reasoning.
Collaborative Discourse	Shift from managerial (>70%) to explanatory talk (>65%) in team meetings.	Not observed in equivalent PBL context. Demonstrates a qualitative shift in collaboration.

Note: M = Mean Score.*.

This consolidated evidence underscores that the curriculum reconstruction effectively promoted the application and transfer of knowledge while fostering the essential cognitive and social processes that characterize deep learning.

4.2 Discussion

4.2.1 Unpacking the Mechanism: How Reconstruction Fosters Depth

The findings can be interpreted through the CLPC theoretical framework to explain the mechanisms by which curriculum reconstruction promotes deep learning. First, the authenticity of the driving question situated abstract biological concepts within a meaningful, agentive context. This aligns with Situated Learning Theory, wherein knowledge is understood as a tool for problem-solving within a community of practice. Students did not learn about ecosystems to pass a test; they learned about nutrient cycles to design a viable compost system. This re-contextualization is the likely driver behind the superior performance on the transfer task, demonstrating knowledge mobility.

Second, the iterative, reflective structure of the CLPC cycle directly scaffolds metacognition. The mandated synthesis and reflection phase institutionalizes the practice of looking back on one's process. The documented increase in metacognitive journal entries is not incidental; it is a direct outcome of this curricular design, which repeatedly creates "cognitive knots" that students must consciously untangle, thereby deepening their understanding of both the content and their own thinking.

Third, the model's embedded collaborative inquiry transforms social interaction from a mere organizational format into an engine for cognitive development, as posited by Socio-cultural Theory. The observed shift from managerial to explanatory discourse indicates that the collaborative task design successfully necessitated the externalization and negotiation of reasoning, a process vital for internalizing complex concepts.

4.2.2 Advancing the Theoretical Dialogue

This study extends the existing literature in two key ways. It strongly supports the body of research advocating for PBL as a means to develop higher-order thinking (e.g., Hmelo-Silver, 2004). However, it adds a critical nuance: the profound gains in transfer and metacognition were observed alongside equivalent gains in basic conceptual knowledge compared to the traditional method. This challenges a common zero-sum assumption that deep, project-based learning comes at the expense of content mastery. Our findings suggest a well-structured, literacy-anchored reconstruction can achieve both.

Furthermore, while prior work has highlighted the importance of collaboration in PBL, our data reveal that the systemic, phased integration of collaboration within the CLPC model was pivotal. Collaboration was not a standalone activity but was purposefully integrated into each project phase (e.g., joint investigation, peer critique of prototypes). This structured integration appears to have fostered the kind of sustained, reasoning-focused dialogue that leads to deeper co-construction of understanding, a finding that moves beyond simply affirming the value of group work.

4.2.3 Implications for Curriculum Design and Teaching Practice

For practitioners, this research underscores that the move towards deep learning requires more than adopting PBL activities; it necessitates a structural rethinking of the curriculum unit. Key actionable implications include: (1) Invest in the Driving Question: Time spent crafting a compelling, open-ended, and literacy-focused driving question is foundational; (2) Plan for the "Messy Middle": Schedules must allocate substantial, flexible time for inquiry and iteration, protecting it from the pressure to "cover content"; (3) Re-tool Assessment: Professional development should support teachers in designing and using competency-focused rubrics for formative feedback throughout the project cycle, not just for judging the final product. The challenges identified, particularly around time and teacher identity, are not failures of implementation but inherent tensions in systemic change, suggesting that support for such reconstruction must be systemic, involving instructional coaches, schedule flexibility, and aligned institutional evaluation policies.

5. Conclusion

This study contributes to the field by moving beyond the promotion of PBL as a standalone pedagogical tool and proposing curriculum reconstruction as a critical mechanism for integrating core literacy development with deep learning. The CLPC model, derived from constructivist, cognitive, and socio-cultural theories, offers a framework for this integration. It shifts from a linear, content-driven curriculum to a dynamic, iterative system, where core literacy anchors an ongoing cycle of inquiry, creation, and reflection.

The primary contribution lies in the empirical evidence. The intervention demonstrated that a restructured curriculum can achieve dual goals: mastering foundational knowledge while fostering superior skills in knowledge transfer, complex reasoning, and metacognitive regulation. This finding challenges the notion that deep learning and content acquisition are mutually exclusive, suggesting they can coexist when the curriculum is designed to integrate both. The study also documents the implementation process, showing both the transformative potential (e.g., shift to collaborative discourse) and challenges (e.g., time constraints, assessment alignment), providing actionable insights for educators.

For educators and leaders, the implications are clear but demanding. Effective implementation requires strategic prioritization of flexible time for iterative project cycles, realignment of assessments to focus on competencies such as collaboration and systems thinking, and targeted professional support for teachers in facilitating inquiry and managing open-ended processes.

The study has limitations, including its focus on a single middle school science unit, which may limit the generalizability of the findings. Challenges and outcomes could vary across disciplines or educational contexts, and the study's duration focuses on initial effects rather than long-term impact.

Future research should explore cross-disciplinary applications of the CLPC model, investigate scaling and sustainability, and conduct longitudinal studies to assess whether the observed gains in deep learning lead to lasting academic and real-world benefits. This study lays the groundwork for further theoretical exploration and transformative classroom practices.

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