

Project-Based Learning and Preschoolers' Collaborative Problem Solving: A Sequential Explanatory Mixed-Methods Protocol Testing Srl Mediation and Scaffolding Moderation

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Abstract: Project-based learning (PBL) is widely promoted in early childhood education as a pedagogy that can cultivate cooperation and problem-solving through sustained inquiry and collaborative artifact construction. However, cooperation and problem solving are often assessed as parallel outcomes, leaving the coordinated process that links them underspecified. Derived from a doctoral dissertation on the coordinated development of preschool children's cooperation and problem-solving ability, this manuscript presents a sequential explanatory mixed-methods protocol (QUAN → QUAL) that conceptualizes coordination as collaborative problem solving (CPS)—the integrated capacity to build shared understanding, coordinate actions, and organize participation toward a joint goal. Using a 12-week quasi-experimental pre-test/post-test design with a matched comparison group, the study tests whether structured PBL produces larger gains in CPS than regular instruction, whether gains are partially explained by improvements in observable self-regulated learning (SRL) routines, and whether teacher scaffolding quality and functional focus strengthen or weaken these pathways. Quantitative evidence comes from performance-based tasks (a triadic CPS task and an individual SRL task) and systematic video coding of scaffolding. Qualitative follow-up uses connected episode selection, teacher interviews, child-stimulated recall, and artifact analysis to explain quantitative patterns through joint displays and meta-inferences. The protocol contributes an operationally detailed, mechanism-oriented blueprint for evaluating how preschool PBL can foster CPS while making feasibility and pathway evidence visible.

Keywords: Project-based learning; Collaborative problem solving; Self-regulated learning; Teacher scaffolding; Preschool education; Sequential explanatory mixed methods

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1. Introduction

Preschool classrooms are social, material, and goal-directed learning environments: children negotiate roles, coordinate bodies and objects, and resolve disagreements while pursuing shared play and learning goals. Accordingly, early childhood curricula increasingly emphasize cooperation and problem-solving as foundational competencies for later learning and participation. Yet classroom instruction and assessment frequently treat these as separate aims—one social, one cognitive—despite the fact that many real-world problems are solved collaboratively.

Project-based learning (PBL) offers an alternative logic. High-quality PBL organizes learning around meaningful questions, sustained inquiry, and the creation of a shared product, making interaction and feedback functionally necessary^[1]. In preschool settings, the project approach has a long tradition of supporting inquiry through observation, representation, and iterative improvement of artifacts^[2]. However, empirical claims about PBL's benefits in early childhood remain difficult to synthesize because measures often fail to capture coordination mechanisms in interaction.

This dissertation-derived study addresses that gap by conceptualizing coordinated development as collaborative problem solving (CPS). CPS is not merely 'working together'; it involves the construction of shared understanding, coordinated action, and team organization that sustains progress toward a joint goal^[3]. From this perspective, coordination becomes visible in how children negotiate criteria, plan jointly, monitor progress against constraints, and repair breakdowns during testing and revision cycles.

A second challenge concerns mechanism and variation. Even when PBL is associated with positive outcomes, effects may vary across classrooms because children's emerging regulation routines and teachers' support practices shape what becomes possible in group work. This protocol foregrounds two explanatory constructs: self-regulated learning (SRL) and teacher scaffolding. SRL is operationalized as observable routines of planning, persistence, strategy switching, monitoring, and reflection—behaviors that are still developing in early childhood^[4]. Teacher scaffolding is defined as contingent support that enables learners to accomplish tasks beyond unassisted performance while progressively transferring responsibility^[5].

The manuscript is a protocol rather than an outcome report. Claims are limited to design rationale, operationalization (tasks, rubrics, coding schemes, and classroom tools), and an evidence-proportionate evaluation plan suitable for naturalistic preschool settings. This approach aims to strengthen transparency and replicability while avoiding overclaiming beyond available evidence^[6].

2. Purpose & objectives

The purpose of this study is to evaluate whether a structured preschool PBL intervention promotes the coordinated development of cooperation and problem-solving ability, operationalized as CPS, and to explain outcome patterns through SRL and teacher scaffolding mechanisms within a sequential explanatory mixed-methods design (QUAN → QUAL).

The specific objectives are to:

- (1) Test whether children in the PBL intervention show greater pre–post gains in CPS than children in a matched comparison condition.
- (2) Examine whether improvements in observable SRL routines partially mediate the relationship between PBL participation and CPS gains.
- (3) Examine whether teacher scaffolding quality and functional focus moderate the PBL → SRL pathway and/or the SRL → CPS pathway.
- (4) Use connected qualitative follow-up (episode selection, interviews, stimulated recall, and artifact analysis) to explain quantitative patterns and support integrated meta-inferences.

3. Literature review / theoretical background

The dissertation framework integrates three theoretical foundations aligned with the thesis outline: constructivist learning theory, sociocultural theory (including the zone of proximal development), and social interdependence theory. Constructivist perspectives emphasize active meaning-making through inquiry, testing, and revision; in PBL, these processes are embedded in sustained projects where ideas are externalized in artifacts. Sociocultural theory highlights mediated action: language and artifacts function as tools for coordinating attention and meaning, and adult guidance can

scaffold participation until children gain greater control. Social interdependence theory underscores that cooperation is not automatic; it is more likely when tasks create positive interdependence and when norms support mutual responsibility^[7].

A key conceptual move is to treat ‘cooperation’ and ‘problem solving’ as a coordinated competence rather than separate endpoints. CPS provides that bridge by defining core coordination mechanisms—shared understanding, coordinated action, and team organization—as the basis for progress in joint tasks. In preschool contexts, CPS is visible in role negotiation, joint monitoring of constraints, and repair sequences during breakdowns (e.g., a collapsed bridge, a failed test).

Mechanistically, SRL and scaffolding provide plausible levers. In early childhood, SRL is closely related to emerging regulatory capacities, but research cautions that self-report is often inappropriate; observable routines and task performance are more valid proxies for young children. Scaffolding research suggests that contingent support and fading are critical: teachers can externalize goals and criteria, model monitoring language, and support inclusion and turn-taking so that regulation becomes shared rather than dominated.

Methodologically, sequential explanatory mixed methods designs offer a strong logic for mechanism-focused inference in real classrooms. Quantitative results establish whether patterns of change occur and which groups differ; qualitative follow-up then explains why patterns occur by tracing processes in selected episodes, with integration achieved through joint displays and meta-inferences.

Taken together, these perspectives motivate a mechanism-focused evaluation. If PBL creates repeated opportunities for inquiry and revision, then children’s emerging regulation routines become a plausible pathway through which coordinated collaboration improves. At the same time, scaffolding is treated as a boundary condition because preschoolers’ participation structures can quickly drift toward dominance, parallel play, or off-task activity without contingent support. Accordingly, the methods section operationalizes CPS, SRL, and scaffolding in observable ways, developmentally appropriate, and directly linkable across QUAN → QUAL integration.

4. Materials and methods

Design approach. The manuscript specifies a sequential explanatory mixed-methods design (QUAN → QUAL) with a quasi-experimental pre-test/post-test structure and a matched comparison group. To strengthen practical relevance and iterative refinement, the intervention toolkit is also described in an educational design research (EDR) spirit: design conjectures are made explicit, and feasibility indicators are built into the evaluation plan^[8].

Materials (PBL toolkit). The minimum-viable preschool PBL toolkit includes: (a) a child-friendly driving-question card and shared project brief; (b) a criteria poster (e.g., “What makes it work?” “What makes it fair/safe?”) used for monitoring; (c) role cards (builder/material manager/tester/recorder) that can rotate; (d) a planning sheet with pictorial prompts; (e) a test log (simple icons for pass/fail and ‘what to change’); (f) reflection prompts (What did we try? What happened? What will we change?); and (g) a teacher micro-conference script emphasising contingent questioning and responsibility transfer. These tools are designed to make coordination and regulation visible through lightweight traces rather than extensive paperwork.

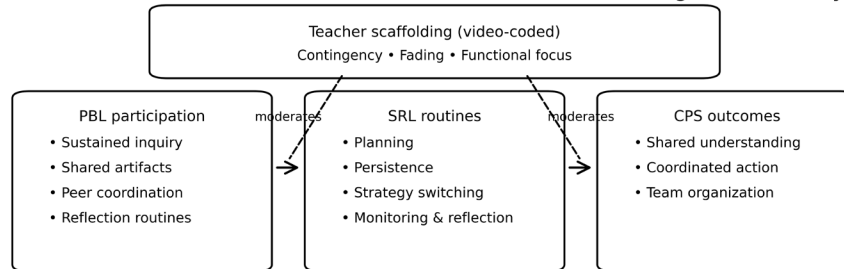
Implementation setting and participants. Fieldwork is conducted in comparable preschool classrooms in Beijing, China. Two intact classes implement the PBL toolkit over 12 weeks, and two intact classes follow the regular curriculum in a matched setting. The target age range is 4–6 years. For performance tasks, children work in triads to ensure manageable coordination and to reduce domination by a single child. Guardian consent and child assent are obtained, and video data are anonymized.

Quantitative measures. CPS is assessed through a standardized triadic performance task (‘Bridge Challenge’) that requires groups to design and build a bridge spanning a fixed gap and supporting a toy car under time and material constraints. Interactions are video-recorded and scored with a process-sensitive rubric aligned to CPS dimensions (shared understanding, coordinated action, team organization). SRL is assessed through an individual task (‘Puzzle Box’) in which children attempt to open a desirable-sticker box with an unfamiliar multi-step latch; behaviors are coded for planning/

inspection, persistence, strategy switching, monitoring, and adaptive help-seeking. Teacher scaffolding is quantified through classroom video coding, capturing contingency and fading, and functional focus (cognitive, metacognitive, social-regulatory).

Evaluation protocol and analysis plan. Quantitative analyses test group-by-time effects (2×2 mixed designs) and examine mediation and moderation via bootstrapped regression models. Qualitative follow-up selects cases and episodes based on quantitative gain profiles (e.g., unexpectedly high/low CPS gains) and analyses critical moments such as disagreement, prototype failure, and revision. Integration uses joint displays that align statistical patterns with episode-based process chains and artifact evidence.

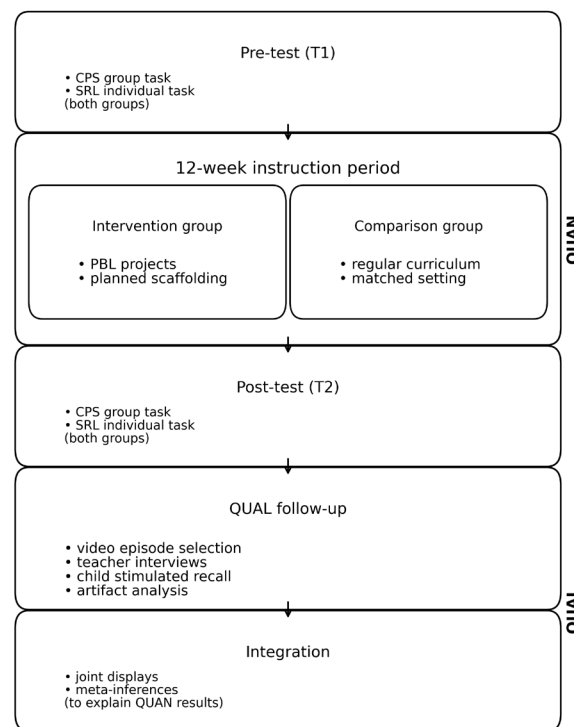
Mediation-Moderation Model (PBL → SRL → CPS) with Teacher Scaffolding as a Boundary Condition



Note. PBL = project-based learning; SRL = self-regulated learning; CPS = collaborative problem solving.

Figure 1. Proposed mediation–moderation model linking PBL, SRL, and CPS with teacher scaffolding as a boundary condition.

Sequential Explanatory Mixed-Methods Design (QUAN → QUAL)



Note. CPS = collaborative problem solving; SRL = self-regulated learning; PBL = project-based learning.

Figure 2. Sequential explanatory mixed-methods design (QUAN → QUAL).

Table 1. Core constructs, operational definitions, and evidence sources

Construct	Operational focus (preschool-adaptive)	Primary evidence sources
Collaborative problem solving (CPS)	Shared understanding, coordinated action, and team organization during joint tasks	Bridge Challenge video + CPS rubric; selected classroom episodes; artifact traces
Self-regulated learning (SRL)	Observable planning, persistence, strategy switching, monitoring/reflection	Puzzle Box video + SRL coding; classroom regulation moves; teacher reflections
Teacher scaffolding	Contingent support, fading/transfer; cognitive/metacognitive/social-regulatory focus	Classroom video coding; teacher interviews; lesson logs/fidelity checks

Table 2. PBL toolkit: tools, evidence traces, and decision triggers for targeted support

Component	Minimum-viable tools	Evidence traces	Decision triggers (examples)
Goal & criteria externalization	Driving-question card; criteria poster	Children's reference criteria; criteria talk during tests	No reference to goals; repeated off-task drift; unclear success criteria
Role organisation	Role cards (rotating)	Balanced participation; role rotation logs	Dominance/withdrawal pattern; role confusion; exclusion episodes
Planning	Pictorial planning sheet	Plan exists before building; plan is revised after feedback	Immediate building without a plan; the plan is not used or revised
Testing & revision	Test log (icons) + 'change' prompt	Recorded pass/fail; explicit change decision; artifact revisions	Repeated failure without a strategy change; no revision after feedback
Reflection & transfer	Brief reflection prompts; photo of product	Child explanations of what changed and why	Inability to explain decisions; purely surface descriptions
Teacher micro-conferences	Contingent question script; fading prompts	Teacher questions elicit child monitoring and decisions	Teacher tells solutions; no responsibility transfer; persistent conflict

Table 3. Evaluation plan (evidence-proportionate): data sources and intended analytic use

Evidence source	Collected at	Primary analytic purpose
CPS triadic task videos + rubric scores	Pre-test (T1) and post-test (T2)	Test group-by-time CPS change; support episode selection
SRL individual task videos + SRL codes	T1 and T2	Test SRL change; evaluate the mediation pathway
Classroom video (selected sessions)	Throughout 12 weeks	Code scaffolding and interaction patterns; provide process evidence
Teacher logs/fidelity checklists	Weekly	Feasibility and implementation fidelity; interpret variation
Teacher interviews	Post-intervention	Explain scaffolding decisions and constraints; triangulate video evidence
Child-stimulated recall	Post-intervention (selected cases)	Elicit child perspectives on goals, choices, and peer work
Artifacts (plans, drawings, prototypes)	Throughout	Trace revision cycles; support joint displays

5. Results

The “results” of this dissertation-derived design protocol are the operationalized PBL-to-CPS mechanism model, the preschool-adaptive toolkit, and the decision rules that make coordinated development visible. **Figure 1** specifies hypothesized pathways: PBL participation is expected to support CPS partly through children's SRL routines, with teacher scaffolding strengthening or weakening pathway translation. **Figure 2** clarifies the QUAN → QUAL integration logic:

quantitative change patterns guide episode selection and qualitative explanation.

To ensure that the paper remains empirically usable (rather than purely conceptual), the protocol specifies admissible evidence for the final results article: (a) episode chains that document planning → monitoring → repair around a shared artifact; (b) triangulation across at least two data sources (video, interview/recall, and artifact traces) for each explanatory claim; and (c) joint displays that align these qualitative chains with the quantitative change profile of the same triad or classroom. These decision rules strengthen the inferential bridge from observed interaction to mixed-methods meta-inference.

Tables 1–3 provide the protocol’s operational core. **Table 1** defines constructs and evidence sources, emphasizing performance-based and observational measures appropriate for preschoolers. **Table 2** lists minimum viable tools and lightweight traces that increase feasibility and make processes observable (planning, monitoring, role organization, and revision cycles). **Table 3** details an evidence-proportionate evaluation plan that supports both quantitative testing and qualitative explanation without assuming intensive measurement at every session.

6. Discussion

This protocol addresses three limitations in preschool PBL research. First, it strengthens construct coherence by operationalizing coordinated development as CPS rather than treating cooperation and problem-solving as separate endpoints. Second, it moves beyond simple ‘PBL vs. non-PBL’ comparisons by specifying a mechanism model in which SRL functions as an explanatory pathway and scaffolding functions as a boundary condition. Third, it embeds integration logic from the outset: qualitative evidence is connected to quantitative variation through purposeful episode selection and joint displays, improving interpretability and practical value.

Several constraints should be acknowledged. Quasi-experimental intact-class designs limit causal attribution; contextual differences may remain after matching. Measurement in young children requires careful interpretation: performance tasks capture competence under structured conditions, while classroom video captures enactment under authentic conditions; both are necessary for credible inference. Finally, scaffolding effects may be highly teacher- and topic-dependent, which strengthens the case for transparent fidelity reporting and for replication across sites.

Future work should (a) evaluate the protocol across diverse preschool settings; (b) test whether shortened project cycles can preserve critical mechanisms (planning, monitoring, repair, revision); and (c) explore how low-burden technology (e.g., simple photo portfolios with time stamps) can support trace collection and reflection while respecting privacy and local ethics.

7. Conclusion

The protocol provides a coherent blueprint for evaluating how preschool PBL can foster coordinated development as CPS. By aligning a preschool-adaptive toolkit with performance-based and observational measures, and by embedding QUAN → QUAL integration logic, the design supports evidence-proportionate testing and explanation of both outcomes and pathways.

Disclosure statement

The authors declare no conflict of interest.

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