3rd International Conference of Bunga Bangsa Cirebon (ICOBBA)
PROCEEDINGS ICOBBA
ISSN : 3032-5641, DOI: 10.47453
Web Journal : https://journal.ljpi.bbc.ac.id/icobba/index

Fostering Inquiry and Curiousity: Project-Based Learning In Early Chldhood Science Education

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Received: 2025-10-28; Accepted: 2026-1-30; Published: 2026-3-12

ABSTRACT

This study aimed to enhance preschoolers' scientific skills through the implementation of Project-Based Learning (PjBL). Using a classroom action research design, the intervention was conducted in three stages—pre-cycle, Cycle I, and Cycle II—with a focus on developing five key skills: observing, questioning, predicting, classifying, and communicating. Data were collected through observation and documentation and analyzed descriptively to capture developmental progress across cycles. The findings indicated substantial improvement in children's engagement and inquiry abilities. The average performance score increased from 2.84 in the pre-cycle to 7.12 in Cycle II, reflecting steady growth in scientific reasoning and curiosity. Children became more confident in formulating questions, expressing predictions, and collaborating with peers. The results confirm that PjBL fosters inquiry-based thinking and supports cognitive, linguistic, and social development in early childhood settings. This research contributes to the understanding of how hands-on, contextualized learning experiences can effectively promote science process skills in young learners and emphasizes the crucial role of teachers as facilitators of inquiry.

Keywords: *Project-Based Learning; preschool science; early childhood education*

INTRODUCTION

Early childhood education (ECE) constitutes a critical period in human development, during which the foundations of cognitive, motor, social, and emotional capacities are established (e.g., National Association for the Education of Young Children [NAEYC] defines early childhood as birth to age eight). In this period, children's brains are extraordinarily plastic, making them receptive to stimulation and learning (Suryana, 2021). Indeed, the first eight years of life are often characterized as a "golden period," because children can absorb and internalize experiences at a pace rarely matched later in life (Pancarita, 2023). Given the formative importance of these years, high-quality pedagogical strategies in early childhood settings are vital for nurturing children's potential and forming a robust foundation for lifelong learning.

Within ECE, early science learning holds particular promise as a means to foster curiosity, inquiry, and problem-solving dispositions in young learners (Hoogland et al., 2024). At its core, science for young children involves engaging them in observing, exploring, questioning, and making sense of phenomena in their everyday environments (Farida, 2021; Pancarita, 2023). This active, inquiry-based view of science aligns with the developmental needs of young children, reinforcing that early engagement in science is not only possible but advantageous (Kurt & Akoglu, 2023; Eliza et al., 2025). However, numerous studies have highlighted that in practice, early childhood science experiences remain superficial, episodic, or teacher-directed rather than child-centered, limiting their impact on children's scientific thinking and reasoning (Eliza et al., 2025; Kurt & Akoglu, 2023).

Despite the recognized importance of early science education, many ECE programs struggle to integrate inquiry and project-based modalities in ways that genuinely activate children's scientific thinking skills. In particular, children frequently display limited abilities in the scientific practices of questioning (the "ask" phase) and communicating findings (the "communicate" phase), according to preliminary observations in a kindergarten class in Cirebon. The kindergarten under investigation (TK Terpadu Salsabil, class B2) showed that, during simple science experiments, children's capacity to formulate meaningful questions and to articulate or share their observations and reasoning was notably weak. This deficit suggests that standard approaches to teaching science—even when hands-on—may not sufficiently scaffold young learners in deeper scientific inquiry.

Project-Based Learning (PJBL) is widely proposed in educational literature as a powerful pedagogical model capable of addressing such deficits (Kurt & Akoglu, 2023). In PJBL, learners engage in extended, student-driven projects that center on real-world problems or phenomena and require sustained inquiry, planning, investigation, and communication (Nghiem et al., 2025). The essential characteristics typically include authentic questions, student voice and choice, continuous reflection, critique and revision, and public products. In the domain of science education, PJBL has been shown to strengthen students' scientific understanding, motivation, higher-order thinking, and 21st-century skills (Kurt & Akoglu, 2023). Meta-analytic evidence indicates that PJBL outperforms traditional instruction in promoting thinking skills and broader learning outcomes (Zhang et al., 2023). In preschool and early childhood settings, a number of studies have extended PJBL principles to inquiry-based STEM or project inquiry formats (Chen & Tippett, 2022), with encouraging but still nascent results.

Within this broader research landscape, some studies have specifically examined PJBL in early childhood science contexts. For instance, a study on project approach–based science programs in preschool demonstrated positive effects on children's problem-solving skills (Haenilah et al, 2021) and other work examined design and implementation of project-based inquiry in preschool STEM settings (Chen & Tippett, 2022). Moreover, a recent systematic review of PJBL in early science education identified that PJBL interventions tend to enhance children's scientific understanding, inquiry skills, and collaboration, though practical challenges and variations in implementation quality limit the consistency of results (DongJin & Ashari, 2024). Nevertheless, there remains a gap: few studies have focused on how PJBL can be tailored specifically to scaffold the ask and communicate stages of the scientific inquiry process in early childhood classrooms, especially in Indonesian kindergarten contexts.

In sum, prior literature suggests that PJBL has promise for fostering inquiry and scientific thinking in early childhood, but does not fully address how to support young learners' questioning and communicative articulation during project phases, and rarely explores implementation in Indonesian preschool settings. To fill this gap, the present study investigates the application of Project-Based Learning in TK Terpadu Salsabil Cirebon, specifically aimed at developing children's scientific inquiry skills—particularly their ability to ask scientifically meaningful questions and to communicate their observations and reasoning.

The objectives of this study are twofold. First, we aim to assess the extent to which PJBL improves scientific inquiry skills, especially in the "ask" and "communicate" phases, among kindergarten children. Second, we seek to identify design features or scaffolding strategies that maximize children's success in those phases of inquiry. This study's novelty lies in bridging the PJBL approach and targeted scaffolding for inquiry stages in an Indonesian early childhood science setting. The findings are intended to inform both theory and practice by offering evidence-based guidelines for implementing PJBL to strengthen young children's scientific thinking in preschool classrooms.

METHOD

This study employed classroom action research (CAR) as its methodological framework. The research design followed the model proposed by Kemmis and McTaggart (1988), which involves iterative cycles of planning, acting, observing, and reflecting. The purpose of using CAR was to systematically improve children's scientific skills through continuous cycles of implementation and evaluation. Each cycle built upon the findings and reflections of the previous one, allowing the researcher to identify effective strategies and make necessary adjustments to improve outcomes.

The intervention was based on Project-Based Learning (PjBL), a pedagogical approach that promotes inquiry, exploration, and problem-solving through meaningful projects. In the context of early childhood education, PjBL allows children to construct knowledge actively, engage in hands-on investigation, and collaborate with peers while developing scientific thinking skills. The PjBL model was chosen because it aligns with the national early childhood education curriculum's emphasis on scientific process skills and child-centered, play-based learning.

The study was conducted in a public early childhood education center located in Cirebon, Indonesia. The participants consisted of 15 children aged 5 to 6 years enrolled in the kindergarten class during the 2024–2025 academic year. The group represented a mixed-gender class with varied developmental levels, typical of early childhood classrooms.

The teacher served as both the classroom practitioner and the primary implementer of the intervention, while the researcher acted as a collaborator and observer. Ethical considerations were addressed by obtaining consent from parents and the school administration. All activities were designed to align with children's developmental characteristics, ensuring that participation was voluntary, safe, and engaging.

The classroom was organized into learning centers to facilitate group activities. Learning materials were primarily composed of low-cost, child-safe items such as natural objects (leaves, stones, seeds), simple measuring tools, containers, and art supplies. These materials were chosen to stimulate exploration while remaining accessible and contextually relevant to children's daily experiences.

A. Indicators of Scientific Skills

The development of scientific skills was measured through five key indicators derived from the national curriculum: observing, questioning, collecting information, associating, and communicating. These indicators reflect the stages of scientific inquiry and align closely with the phases of PjBL. Each indicator was operationalized through specific teacher actions and child activities during the two research cycles.

1. Observing

   Observation formed the foundation of all scientific exploration. In this stage, the teacher introduced natural and familiar materials—such as plants, water, soil, and seeds—to stimulate sensory engagement. The teacher guided the children to use their senses intentionally, asking prompts like, "What do you see?" "What do you feel?" "How does it smell?" Children were encouraged to notice details such as shape, color, and texture.

   To support systematic observation, the teacher modeled descriptive language and encouraged children to express what they saw through drawings or verbal descriptions. For instance, after observing leaves, children drew their shapes and discussed their differences. These activities nurtured curiosity, sharpened attention, and laid the groundwork for inquiry-based reasoning.

2. Questioning

   Once children had gathered initial observations, the teacher guided them to express their curiosity through questions. At first, the teacher modeled questioning behavior, asking "Why do you think the leaf is green?" or "What will happen if we put this in water?" As the cycles progressed, children began to formulate their own questions spontaneously.

   In Cycle I, teacher scaffolding was dominant, with most questions prompted by the teacher. In Cycle II, children showed greater independence and confidence in asking "what," "why," and "how" questions. The teacher created a safe environment for exploration by validating every question, no matter how simple or unexpected. This open dialogue encouraged critical thinking and positioned questioning as a natural step in scientific inquiry.

3. Collecting Information

   In this phase, children conducted simple, age-appropriate experiments or explorations to seek answers to their questions. Activities included observing which objects sink or float, growing seeds in different conditions, or mixing primary colors to form new ones. The teacher prepared the materials, ensured safety, and encouraged children to manipulate objects freely.

The children worked collaboratively in small groups to gather data. The teacher guided them to make comparisons, measure using non-standard units (e.g., "Which cup has more water?"), and record results through drawings or storytelling. Rather than providing explanations directly, the teacher encouraged children to verbalize their observations and test their assumptions. This hands-on process fostered independence, curiosity, and evidence-based reasoning.

4. Associating

   The associating stage involved interpreting and connecting the information gathered. The teacher prompted reflective thinking by asking questions such as "What did you find out?" "Why do you think that happened?" and "What is the same or different between the two plants?" Through these discussions, children were guided to identify simple relationships and patterns—for example, realizing that "plants grow better with sunlight" or "heavy things sink."

   The teacher used storytelling, comparison charts, and group discussions to help children relate new findings to prior experiences. This encouraged them to construct meaning collaboratively, consistent with socio-constructivist learning principles. Over time, children began articulating cause-and-effect reasoning more clearly, showing an increased ability to connect observations with logical explanations.

5. Communicating

   The final indicator involved sharing findings with peers and teachers. The teacher organized opportunities for children to present their projects through oral explanations, show-and-tell sessions, drawings, or simple displays. Each group was encouraged to explain what they did, what they found, and what they learned.

   For instance, children who observed plant growth presented their results by showing pictures of their plants and explaining which one grew fastest. The teacher guided them to use complete sentences and scientific vocabulary, such as grow, light, water, or compare. Peers were invited to ask questions, reinforcing social and linguistic development.

B. Research Procedure

The study was conducted through one pre-cycle and two action research cycles, each consisting of the four stages of planning, action, observation, and reflection. Cycle I (Exploration and Introduction Stage): In this initial cycle, the focus was on introducing the PjBL framework and establishing routines for observation, questioning, and exploration. The teacher designed a project around simple natural phenomena—such as the growth of plants—to introduce children to scientific exploration. Observation sheets, photos, and anecdotal notes were used to record childen's responses.

Cycle II (Development and Deepening Stage): Adjustments were made based on the reflection from Cycle I, including clearer instructions, more varied materials, and structured opportunities for children to ask and answer questions. This cycle emphasized associating and communicating skills, where children were guided to analyze and present findings more systematically. Each cycle lasted approximately one week, with three classroom sessions per week. The data were collected through direct observation, documentation of children's work, and reflection notes from both teacher and researcher.

C. Data Collection and Analysis

Data were gathered using multiple methods to ensure reliability and triangulation. Observation checklists were used to record the frequency and quality of scientific behaviors according to the five indicators. Anecdotal records captured qualitative descriptions of children's interactions and verbal expressions. Documentation (drawings, photos, and project artifacts) provided visual evidence of learning progression.

Data analysis was conducted through both quantitative and qualitative approaches. Quantitative analysis involved scoring children's performance using a rubric aligned with each indicator, while qualitative analysis focused on identifying behavioral patterns and thematic trends. The reflective discussions between the teacher and the researcher after each cycle served as a mechanism for continuous improvement.

The results of the analysis were used to revise instructional strategies and materials for subsequent cycles. This cyclical process ensured that changes were responsive to children's needs and that the development of scientific skills could be traced progressively across both cycles. The criteria for assessing children's learning mastery were adapted from Casta (2014). Scores ranging from 86% to 100% were categorized as very good, 76% to 85% as good, 60% to 75% as fairly good, 55% to 59% as less good, and below 54% as very poor. These categories provided a standardized benchmark for interpreting the improvement of children's scientific skills across the two research cycles.

RESULTS AND DISCUSSION

The study aimed to enhance preschoolers' scientific skills through the implementation of Project-Based Learning (PjBL). The findings were obtained across three stages: pre-cycle, Cycle I, and Cycle II. Each stage reflected progressive improvement in children's ability to observe, ask questions, predict, classify, and communicate their findings. Overall, the results indicate that PjBL created a meaningful, hands-on learning experience that significantly fostered young learners' inquiry and problem-solving abilities in science contexts.

A. Pre-cycle Results

	Observing (ND/D)	Questioning (ND/D)	Collecting Information (ND/D)	Associating (ND/D)	Communicating (ND/D)	Result (ND/D)
Percentage	0% / 100%	80% / 20%	40% / 60%	40% / 60%	80% / 20%	28%/72%
Interpretation	Very Good	Very Poor	Fairly Good	Fairly Good	Very Poor	Good

Description:
Not Yet Developed : ND
Developed : D

Table 1. Pre-cycle Results

During the pre-cycle phase, most children demonstrated minimal scientific engagement. Observations revealed that many students struggled to formulate questions, make predictions, or articulate their observations. The average performance score was 2.84, which fell into the "very low" category. Children were often passive during activities, tended to follow instructions mechanically, and rarely initiated inquiry on their own. These findings align with prior research indicating that preschool children often require structured facilitation to engage in scientific reasoning (Hardy et al., 2022).

Furthermore, teacher–child interactions were mostly directive rather than exploratory. The classroom environment emphasized completion of tasks rather than discovery, resulting in limited opportunities for experimentation. This pattern is consistent with findings by Fleer (2021), who argued that when early science experiences are dominated by rote or teacher-led instruction, children's curiosity and reasoning abilities are constrained. The low baseline thus reflected a need for a pedagogical model that allows children to explore, manipulate materials, and construct understanding through experience—core elements of PjBL.

B. 3.2 Cycle I Results

	Observing (ND/D)	Questioning (ND/D)	Collecting Information (ND/D)	Associating (ND/D)	Communicating (ND/D)	Result (ND/D)
Total	0 / 45	22 / 23	7 / 38	15 / 30	19 / 26	63/162
Percentage	0% / 100%	49% / 51%	15% / 84%	33% / 67%	42% / 58%	28%/72%
Interpretation	Very Good	Fairly Good	Good	Fairly Good	Less Good	Good

Table 2. Cycle I Results

The analysis of scientific skill indicators revealed that children demonstrated consistent improvement in all domains. In the observing indicator, all children (100%) were categorized as "emerging" by the third meeting. For questioning, performance was nearly balanced, with 49% in the "not yet developed" category and 51% in the "developing" category, indicating a steady increase in children's ability to express curiosity and pose questions. The collecting information indicator showed 84% of children demonstrating improvement, suggesting that hands-on exploration and experimentation were effective in fostering investigative behavior. In associating, 67% of children achieved a "developing" level, reflecting progress in connecting information and forming simple conclusions. Finally, in communicating, 58% reached the "developing" stage, indicating growth in children's confidence and ability to share ideas with peers. Overall, the data suggest a strong positive trend in scientific skill development through the implementation of Project-Based Learning.Children became more interested in the learning process and started to ask questions about observable phenomena, such as "Why does the water move?" or "What will happen if we mix these colors?" This behavioral shift illustrates the early emergence of inquiry, one of the foundational aspects of scientific thinking (Osterhaus et al., 2021).

Classroom observations revealed that hands-on projects—such as creating simple water filters or growing plants—successfully stimulated children's curiosity and reasoning. They began making tentative predictions and sharing ideas with peers, although their vocabulary and conceptual clarity were still limited. Teachers reported that children enjoyed group collaboration and demonstrated longer attention spans during experiments. This aligns with Shin (2018), who found that early learners engaged in project-based activities exhibit enhanced motivation and sustained participation.

Despite these positive developments, certain challenges persisted. Some children required extensive teacher scaffolding to maintain focus or articulate their observations. The teacher's role in Cycle I therefore emphasized modeling inquiry-based dialogue—asking open-ended questions and guiding children to reflect on their findings. As Piasta et al. (2022) highlighted, effective teacher mediation is critical for developing science talk and reasoning in early childhood contexts. The findings from Cycle I suggest that while PjBL encouraged active learning, the children were still in the process of internalizing inquiry routines and collaborative reflection.

C. Cycle II Results

	Observing (ND/D)	Questioning (ND/D)	Collecting Information (ND/D)	Associating (ND/D)	Communicating (ND/D)	Result (ND/D)
Total	0 / 45	12 / 33	2 / 43	7 / 38	10 / 35	31/194
Percentage	0% / 100%	27% / 73%	4% / 96%	16% / 67%	22% / 78%	14%/86%
Interpretation	Very Good	Good	Very Good	Good	Good	Very Good

Table 3. Cycle II Results

The results of Cycle II demonstrated a significant improvement across all indicators of scientific skills. In the observing indicator, 100% of children achieved the "developed" level, categorized as very good. The questioning indicator showed 73% of children reaching the "developed" stage, an improvement from the previous cycle, with an overall interpretation of good. For collecting information, 96% of children demonstrated developed skills, reflecting a very good category. Similarly, associating reached 84% and communicating 78%, both categorized as good to very good. Children were more confident in expressing ideas, forming hypotheses, and evaluating outcomes. For example, when exploring the concept of floating and sinking, several children were able to predict accurately which objects would float and later justify their reasoning using observable evidence. Such examples highlight the transition from simple manipulation of materials to early forms of scientific reasoning, consistent with the stages of inquiry proposed by Siraj-Blatchford et al. (2002).

Children also exhibited enhanced collaboration and communication skills. They discussed observations among peers, recorded results with drawings, and explained processes in their own words. Teachers reported that children began transferring scientific reasoning to other classroom contexts, such as discussing weather changes or cooking activities.

Moreover, the learning environment became more dynamic and student-centered. The teacher's role shifted from instructor to facilitator, promoting inquiry-based questioning and guiding reflection. This pedagogical shift is supported by findings from Jang et al. (2016), who noted that when teachers adopt a facilitative stance, young learners exhibit greater autonomy and conceptual understanding in science learning. The combination of hands-on experimentation, peer collaboration, and guided reflection contributed to significant gains in the children's inquiry processes.

D. Comparative Analysis Across Cycles

Description	Percentage	Interpretation
Pre-cycle	20%	Very Poor
Cycle I	72%	Good
Cycle II	86%	Very Good

Table 4. Comparative results across Cycles

The recapitulation of the scientific skill development at Salsabil Integrated Kindergarten showed a steady improvement across research cycles. In the pre-cycle stage, children's scientific skills were categorized as very poor with an average achievement of 20%. After the implementation of Project-Based Learning (Cycle I), the results increased significantly to 72%, categorized as good. By Cycle II, the percentage rose further to 86%, indicating a very good level of scientific skill mastery among the children.

The comparison clearly illustrates a consistent upward trend in all components of scientific skills. Children's ability to observe carefully, formulate questions, predict outcomes, and communicate findings improved steadily throughout the intervention. In qualitative terms, the children moved from passive receivers of information to active constructors of knowledge. These findings corroborate previous studies demonstrating that PjBL enhances cognitive engagement and higher-order thinking in early science education (Nasution & Setyaningrum, 2024).

The most substantial progress was noted in children's communication and collaboration skills. Initially, students hesitated to share their thoughts or question peers' ideas. By Cycle II, they were confidently presenting group findings and negotiating meanings within their teams. According to Vygotskian theory, such social interaction within the Zone of Proximal Development is essential for advancing cognitive and linguistic growth (Fleer, 2021). The children's growing ability to articulate reasoning suggests that PjBL not only improved conceptual understanding but also fostered language development and social competence.

In addition, the iterative cycle design of the study allowed for continuous reflection and adaptation. Teacher feedback after Cycle I led to refinements in classroom management and material selection, resulting in more efficient facilitation during Cycle II. The process of revising instructional strategies based on observation aligns with the action research model, which emphasizes responsiveness and contextual adaptation (Mertler, 2023). This cyclical reflection strengthened both teaching quality and learning outcomes.

E. Discussion

The findings from this study affirm the effectiveness of Project-Based Learning in promoting scientific skills among preschool children. PjBL provides a constructivist framework where children learn through authentic projects, inquiry, and collaboration. The observed improvement across the three cycles substantiates earlier evidence that experiential learning environments are more effective than traditional teacher-centered models in fostering early scientific thinking (Granger et al., 2012).

One key factor contributing to the success of PjBL was its emphasis on meaningful context. Each project was linked to children's real-life experiences, such as water play, plant growth, or simple engineering activities. According to Helm et al. (2023), children are more likely to engage deeply in scientific reasoning when they see direct connections between learning activities and their everyday world. Such contextualized learning also supports sustained motivation and curiosity, both of which were evident as the cycles progressed.

Teacher facilitation also played a central role. The transition from a directive to a facilitative teaching approach empowered children to lead their own inquiries. This aligns with the findings of Uiterwijk-Luijk et al. (2019), who emphasized that teachers who model inquiry language and encourage exploration help children internalize scientific habits of mind. The gradual reduction of scaffolding over time encouraged autonomy and self-regulation—skills that are essential for lifelong learning.

The study's results also highlight the importance of social interaction in the development of early scientific reasoning. PjBL encouraged children to collaborate, negotiate, and articulate ideas in shared problem-solving contexts. This aligns with sociocultural perspectives asserting that cognitive development is mediated by language and social engagement (Vygotsky, as cited in Fleer, 2021). Through dialogue and cooperation, children not only built understanding of scientific phenomena but also developed communicative competence and empathy.

Another significant implication of this research lies in its contribution to the understanding of how inquiry-based pedagogy can be operationalized in preschool contexts. Although many teachers recognize the value of inquiry, they often struggle with its practical implementation. The results of this study provide empirical evidence that PjBL can be adapted effectively for young learners when guided by structured cycles, responsive facilitation, and contextually relevant materials. This confirms the applicability of PjBL beyond primary or secondary education, supporting its relevance in early childhood settings (Aisyah & Novita, 2025).

Finally, the progressive enhancement of children's scientific skills across cycles underscores the importance of sustained, reflective practice in teacher development. The iterative design not only improved children's outcomes but also deepened the teacher's understanding of inquiry pedagogy. As noted by Kangas (2010), teachers who continuously reflect and adapt instructional strategies are more likely to foster active, playful learning environments that enhance both cognitive and emotional growth.

CONCLUSION

This study demonstrated that the implementation of Project-Based Learning (PjBL) significantly improved preschoolers' scientific skills, particularly in observation, questioning, predicting, classifying, and communicating findings. Across three stages—pre-cycle, Cycle I, and Cycle II—children showed a clear transition from passive participation to active, inquiry-driven engagement. The final cycle revealed not only cognitive improvement but also enhanced collaboration, communication, and self-confidence. These findings suggest that PjBL creates a meaningful learning environment that bridges experiential play with structured scientific reasoning.

Theoretically, the study contributes to the growing body of research supporting inquiry-based pedagogies in early childhood education. It affirms that even at the preschool level, scientific reasoning can be effectively nurtured when learning is contextual, collaborative, and reflective. Practically, this study highlights the importance of teacher facilitation and reflective practice in implementing PjBL successfully. Further research could explore longitudinal impacts of PjBL on sustained scientific reasoning and how digital or outdoor contexts might expand its effectiveness in early education settings.

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