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EXPERIMENTAL SCIENCE LEARNING AS AN INQUIRY-BASED PEDAGOGICAL FRAMEWORK FOR FOSTERING COGNITIVE DEVELOPMENT IN EARLY CHILDHOOD EDUCATION

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Abstract

This study examines how experimental science learning fosters the cognitive development of children aged 5–6 years in early childhood education. Although previous studies have established the effectiveness of science experiments in improving science process skills and learning engagement, limited attention has been given to how inquiry experiences shape children's causal reasoning through contextual learning. This study addresses that gap by proposing experimental science learning as an integrated pedagogical framework linking contextual planning, inquiry-based implementation, and authentic assessment to children's cognitive development. The findings identify six interconnected inquiry stages that progressively support logical thinking and conceptual construction. This research employed a qualitative descriptive case study at KB Raudlatul Ulum, Jember City. The participants comprised 20 Group B children, while the school principal, one classroom teacher, and one assistant teacher served as key informants. Data were collected through participant observation, semi-structured interviews, documentation, and supporting questionnaires, then analyzed using an interactive qualitative approach involving data reduction, data display, and conclusion drawing. Credibility was strengthened through method and source triangulation. The findings indicate that contextual lesson planning, inquiry-oriented classroom interaction, and continuous authentic assessment collectively promoted children's observation, prediction, evidence verification, and reflective reasoning. Rather than merely introducing scientific concepts, experimental science learning facilitated the progressive construction of causal understanding, logical reasoning, and scientific habits of mind, highlighting inquiry as a comprehensive pedagogical process for strengthening early childhood cognitive development.

Keywords: authentic assessment; cognitive development; early childhood education; experimental science learning; inquiry-based learning

Abstrak. Penelitian ini meneliti bagaimana pembelajaran sains eksperimental mendorong perkembangan kognitif anak-anak berusia 5–6 tahun dalam pendidikan anak usia dini. Meskipun penelitian sebelumnya telah menetapkan efektivitas eksperimen sains dalam meningkatkan keterampilan proses sains dan keterlibatan belajar, perhatian terbatas telah diberikan pada bagaimana pengalaman penyelidikan membentuk penalaran kausal anak-anak melalui pembelajaran kontekstual. Studi ini mengatasi kekurangan tersebut dengan mengusulkan pembelajaran sains eksperimental sebagai kerangka pedagogis terintegrasi yang menghubungkan perencanaan kontekstual, implementasi berbasis penyelidikan, dan penilaian autentik dengan perkembangan kognitif anak-anak. Temuan penelitian ini mengidentifikasi enam tahap penyelidikan yang saling terkait yang secara progresif mendukung pemikiran logis dan konstruksi konseptual. Penelitian ini menggunakan studi kasus deskriptif kualitatif di KB Raudlatul Ulum, Kota Jember. Pesertanya terdiri dari 20 anak Kelompok B, sementara kepala sekolah, satu guru kelas, dan satu guru pembantu bertindak sebagai informan kunci. Data dikumpulkan melalui observasi partisipatif, wawancara semi-terstruktur, dokumentasi, dan kuesioner pendukung, kemudian dianalisis menggunakan pendekatan kualitatif interaktif yang melibatkan reduksi data, tampilan data, dan penarikan kesimpulan. Kredibilitas diperkuat melalui triangulasi metode dan sumber. Temuan menunjukkan bahwa perencanaan pelajaran kontekstual, interaksi kelas yang berorientasi pada penyelidikan, dan penilaian autentik yang berkelanjutan secara kolektif mendorong pengamatan, prediksi, verifikasi bukti, dan penalaran reflektif anak-anak. Alih-alih hanya memperkenalkan konsep-konsep ilmiah, pembelajaran sains eksperimental memfasilitasi konstruksi progresif pemahaman kausal, penalaran logis, dan kebiasaan berpikir ilmiah, menyoroti penyelidikan sebagai proses pedagogis yang komprehensif untuk memperkuat perkembangan kognitif anak usia dini.

Kata Kunci : penilaian autentik; perkembangan kognitif; pendidikan anak usia dini; pembelajaran sains eksperimental; pembelajaran berbasis inquiry

Background

Cognitive development in early childhood does not occur as a process of passively receiving information, but rather as a process of building understanding thru direct interaction with the surrounding world (Rakesh et al., 2024). Children construct their own knowledge when they are given space to observe, explore, and test various phenomena they encounter daily (Istiqomah & Maemonah, 2021). Consequently, the ideal early childhood education curriculum is designed not merely as the delivery of content, but as a series of experiences that allow children to find meaning in the concrete activities they engage in themselves (O'Connor et al., 2021). Science learning occupies a strategic position within this framework because it gives children the opportunity to construct concepts from empirical experiences, allowing their ability to think logically, reason, and solve problems to develop gradually (Rahardjo, 2019).

Science education for young children is essentially not aimed at mastering complex scientific concepts, but rather at fostering scientific thinking skills thru simple investigations that are close to the child's daily life (Koerber & Osterhaus, 2019). Activities such as observing, grouping, comparing, predicting, and communicating observation results are a series of scientific process skills that play an important role in developing cause-and-effect thinking abilities (Izzuddin, 2021). When a child is given the opportunity to conduct experiments directly, they learn to connect an action with its consequences based on evidence they obtain themselves, not just based on adult explanations (Weisberg & Sobel, 2022). Experiences like this make learning more meaningful compared to verbal delivery of material, because knowledge grows from the exploration process that children truly experience (O’Connor et al., 2021).

Although science education plays a strategic role in the development of children's thinking, its practice in various early childhood education units still leaves several issues. Some studies show that learning activities tend to be teacher-centered, leaving relatively little room for children to engage in scientific exploration (Husin & Yaswinda, 2021). Teachers more often rely on oral explanations, demonstrations, or worksheets as the main activities, while experimental activities are only conducted occasionally (Hidayati & Suryana, n.d.). The situation limits children's opportunities to hone their observation skills, engage in scientific reasoning, and understand cause-and-effect relationships thru authentic learning experiences (Hasibuan and Suryana 2021).

A similar issue is also evident in Group B of KB Raudlatul Ulum in Jember City. Initial observations indicate that several children still struggle to understand how an event occurs and are unable to explain cause-and-effect relationships in a coherent manner. Children's involvement in exploratory activities is also not optimal, so the learning process has not fully encouraged the development of scientific thinking. This field condition indicates the need for a more contextual and exploratory-oriented science learning approach, with stages of observing, classifying, predicting, proving, and drawing conclusions based on the child's direct experience.

The development of studies on early childhood science education in recent years has shown an increasingly strong tendency toward inquiry-based and hands-on approaches. Rahardjo's research shows that the application of a scientific approach can significantly develop children's science process skills, from observing to communicating experimental results (Rahardjo, 2019). The findings are in line with the study by Amantika, Aziz, and Travelancya, which emphasizes that simple experimental methods can enhance children's ability to recognize concepts and relationships between phenomena more concretely (Amantika et al., 2022). Meanwhile, Susilawati and Sumitra added that the effectiveness of science learning is not solely determined by the experiments themselves, but also by the teacher's ability to present a familiar surrounding context for the children (Susilawati & Sumitra, 2021).

Although various studies have proven the benefits of experimental-based learning, the focus of research is still largely centered on the development of science process skills and learning motivation alone. These studies have not extensively explored how experimental experiences help children develop cause-and-effect thinking skills thru phenomena that are close to their daily lives.

The differing focuses of these studies indicate that the relationship between science experiments and cognitive development still leaves room for further exploration. Most studies evaluate the improvement in learning outcomes or science process skills, while the process of developing causal thinking abilities, which is central to children's cognitive development, has not been comprehensively described. The use of learning contexts derived from surrounding environmental phenomena is still relatively limited, even tho contextual experiences are easier for children to understand because they are directly related to the realities they encounter every day. Therefore, a study is needed that not only measures learning outcomes but also explains how experimental experiences shape children's thinking processes during the activities.

Based on these conditions, this research focuses on the implementation of science learning thru experimental methods as a strategy to develop the cognitive abilities of early childhood, particularly in understanding cause-and-effect relationships. Unlike some previous studies that emphasized learning outcomes, this research delves deeper into the learning process from the planning stage, implementation, to the learning experiences children undergo during the experimental activities. This approach is expected to provide a more comprehensive understanding of the mechanisms of developing logical thinking skills thru scientific activities that align with the developmental characteristics of children, while also addressing the issue found at the research site, namely the limited ability of children to logically connect an event with its cause and effect.

Method

This study employed a qualitative descriptive case study to obtain an in-depth understanding of how experimental science learning was implemented to support early childhood cognitive development. A qualitative approach was selected because the study sought to explore instructional practices, classroom interactions, and children's learning experiences within their natural setting rather than examining causal relationships through numerical measurement. The case study design was considered appropriate because the investigation focused intensively on a single educational setting, following the argument that case studies allow researchers to strengthen the validity and reliability of qualitative findings through in-depth, bounded inquiry (Quintão et al., 2020), thereby enabling a comprehensive understanding of the implementation of experimental science learning in Group B at KB Raudlatul Ulum, Jember City.

The study focused on Group B children aged 5–6 years as the primary participants, while the school principal, the classroom teacher, and the assistant teacher served as key informants to provide complementary perspectives regarding instructional planning, implementation, and evaluation. Focusing on a single classroom enabled the researcher to examine the learning process comprehensively and to capture contextual factors influencing children's cognitive development during science learning activities.

Data were collected through participant observation, semi-structured interviews, documentation, and supporting questionnaires. Participant observation allowed the researcher to directly examine children's engagement and teacher–child interactions during experimental activities. Semi-structured interviews were conducted to explore teachers' instructional decisions and classroom experiences in greater depth, while documentation was used to verify lesson plans, learning materials, and assessment records. Questionnaires served as complementary evidence to strengthen the interpretation of observational findings rather than as the primary source of data.

The collected data were analyzed through an interactive qualitative analysis consisting of data reduction, data display, and conclusion drawing. Rather than treating analysis as a separate stage, data collection and interpretation were conducted iteratively, allowing emerging findings to guide subsequent observations and interviews, in line with recommendations for maintaining rigor and reflexivity throughout the coding and interpretation process in qualitative inquiry (Braun & Clarke, 2021). To ensure the credibility of the findings, evidence obtained from observations, interviews, documentation, and questionnaires was continuously compared using method triangulation and source triangulation, thereby increasing the consistency and trustworthiness of the interpretations across different data sources.

Result and Discussion

Result

The findings indicate that experimental science learning at KB Raudlatul Ulum was implemented as an integrated learning process that connected instructional planning, inquiry-oriented classroom activities, and continuous assessment. Data obtained from classroom observations, interviews, documentation, and supporting questionnaires showed that the learning process was designed around children's direct experiences with familiar phenomena and natural materials. The implementation then engaged children in a sequence of inquiry activities that included observation, exploration, prediction, experimentation, evidence verification, and knowledge construction. Throughout these activities, teachers continuously documented children's responses, explanations, and ways of reasoning as part of the assessment process. The main findings are summarized in Table 1.

As shown in Table 1, the findings reveal three interconnected characteristics of experimental science learning in the observed classroom. First, instructional planning was contextualized and inquiry-oriented, as teachers selected learning experiences and materials that were familiar to children and organized activities into a sequence that allowed children to construct understanding through direct experience. Second, implementation was characterized by active inquiry, in which children were given opportunities to observe, manipulate materials, formulate predictions, test their ideas, examine evidence, and communicate explanations. The field data further showed that these activities involved six interconnected processes: observation, research process through direct manipulation of materials, grouping, prediction, evidence discovery, and knowledge construction. Third, assessment was conducted continuously throughout the learning process. Rather than assessing children only according to whether they obtained the expected experimental result, teachers documented how children observed phenomena, formulated predictions, responded to unexpected outcomes, interpreted evidence, revised their initial ideas, and explained what they had discovered. The observed assessment practices included observational records, anecdotal notes, children's work products, and classroom documentation.

Table 1. Main Findings of Experimental Science Learning and Children's Cognitive Development

Main Finding	Specific Findings	Empirical Indicators Observed	Data Sources
Contextual and inquiry-oriented instructional planning	Learning objectives were adjusted to children's developmental characteristics, and experimental activities were selected from phenomena and materials familiar to children.	Teachers selected simple materials such as water, colors, plants, stones, and other natural materials. Learning activities were organized sequentially to provide opportunities for children to observe, explore, predict, experiment, verify evidence, and construct understanding.	Participant observation, semi-structured interviews, and documentation
Inquiry-oriented implementation supported children's cognitive processes	Experimental learning was implemented through active participation and a sequence of interconnected inquiry activities rather than through teacher explanation alone.	Children observed objects, manipulated materials, identified similarities and differences, formulated predictions, conducted experiments, compared predictions with observed evidence, and communicated explanations. Teacher–child interaction emphasized guiding questions and exploration rather than immediate provision of answers.	Participant observation, semi-structured interviews, and supporting questionnaires
Continuous authentic assessment captured children's developing reasoning	Assessment was integrated into the experimental process and focused on children's thinking processes rather than only on final products or correct answers.	Teachers used observation records, anecdotal notes, children's work, and classroom documentation to identify children's ability to observe, predict, explain outcomes, compare evidence, revise explanations, and communicate their understanding. Assessment findings were also used to adjust questioning, scaffolding, and subsequent learning activities.	Participant observation, semi-structured interviews, documentation, and supporting questionnaires

Taken together, the findings demonstrate that experimental science learning in this setting was not implemented as an isolated experiment or a one-time activity. Instead, it operated as a coherent sequence in which contextual planning provided the foundation, inquiry-oriented activities constituted the learning process, and continuous authentic assessment documented children's developing reasoning. The three findings presented in Table 1 therefore represent the central empirical results of the study and provide the basis for the subsequent discussion.

Discussion

The first finding demonstrates that the quality of experimental science learning was closely associated with how teachers planned learning experiences before classroom implementation. The teacher did not begin with abstract scientific concepts but selected phenomena and materials that children already encountered in their everyday environment. Water, colors, plants, stones, and other natural materials were used as concrete starting points for scientific exploration. This planning enabled children to encounter scientific phenomena through direct experience before being expected to articulate an explanation. The findings therefore indicate that contextualization was not merely a strategy for making activities interesting; it provided an accessible starting point for children to develop explanations from what they could directly observe.

This finding indicates that contextual lesson planning served an important cognitive function beyond classroom management. From a constructivist perspective, children's understanding develops when they actively reorganize existing cognitive structures through interactions with meaningful experiences rather than through passive information reception (Taber, 2024). Consequently, selecting familiar experimental contexts reduced children's cognitive burden while simultaneously increasing opportunities for reflective thinking and causal reasoning. The planning process therefore acted as cognitive scaffolding that enabled children to transform concrete observations into conceptual understanding through continuous interaction with their environment (Ma et al., 2022).

This interpretation extends previous findings reported by O'Connor, Fragkiadaki, Fleer, and Rai, who argued that inquiry-oriented science learning improves children's engagement by encouraging direct exploration from the earliest years of schooling. While their review primarily emphasized children's participation during scientific inquiry in general, the present findings suggest that children's engagement is strongly influenced by the quality of instructional planning conducted before classroom activities begin (O’Connor et al. 2021). Similarly, Weisberg and Sobel (2022) demonstrated that young children's causal reasoning abilities are more readily activated when experimental tasks are grounded in familiar, everyday contexts rather than abstract or unfamiliar materials (Weisberg & Sobel, 2022). However, the current study further illustrates that contextual lesson preparation facilitates children's causal reasoning because familiar situations encourage them to formulate predictions, compare evidence, and revise their initial assumptions more confidently.

These findings also contribute to a broader understanding of early childhood science pedagogy. Existing literature frequently positions experimental activities as instructional techniques for increasing children's interest in science. The present findings suggest a more comprehensive interpretation: experimental science learning functions as a pedagogical mechanism through which children progressively organize logical thinking, construct causal explanations, and develop scientific habits of mind. Consequently, the effectiveness of experimental learning depends less on sophisticated instructional media than on teachers' pedagogical capacity to transform everyday experiences into systematic opportunities for scientific inquiry, a conclusion that resonates with Gözüm, Papadakis, and Kalogiannakis, who found that teachers' pedagogical content knowledge for STEM-related activities substantially shapes the quality of science experiences made available to young children (Gözüm et al., 2022). This perspective broadens current discussions on inquiry-based learning by emphasizing that instructional planning itself represents a crucial determinant of children's cognitive development during early science education.

The second finding concerns the implementation of experimental science learning. The classroom observations showed that children were actively involved in observing phenomena, manipulating materials, making predictions, comparing outcomes, and communicating explanations. The teacher's role shifted from providing direct explanations toward facilitating children's investigation through guiding questions. This interaction allowed children to examine whether their initial ideas corresponded with what they observed during experimentation.

A particularly important aspect of the findings was the presence of six interconnected inquiry processes: observation, research process, grouping, prediction, evidence discovery, and knowledge construction. During observation, children examined the characteristics of objects using their senses. The research process involved direct manipulation of materials and observation of changes resulting from children's actions. Grouping involved identifying similarities and differences, while prediction required children to express expectations concerning possible outcomes. Evidence discovery occurred when children compared their expectations with what happened during experimentation. The final process, knowledge construction, involved children's attempts to communicate findings and explain why particular changes occurred.

The significance of these findings lies in the continuity among the processes. Children's participation was not limited to carrying out experimental procedures. They were also encouraged to explain what they observed and reconsider their initial ideas after encountering evidence. Classroom interaction therefore created opportunities for children to connect prior experiences with new observations. The teacher's questioning was particularly important because children were not immediately provided with explanations when their predictions differed from the experimental results. Instead, they were encouraged to examine the evidence and articulate their own understanding.

The present findings also reinforce sociocultural perspectives of learning, which emphasize that cognitive development emerges through meaningful interaction between children, teachers, peers, and learning environments (Wibowo et al., 2025). Throughout the experimental sessions, teachers continuously prompted children to explain observations, compare opinions, and justify conclusions using evidence generated during experimentation. Such dialogic interaction transformed experimentation into a collaborative inquiry process rather than an individual trial-and-error activity. Consequently, scientific understanding was constructed collectively through communication and reflection, enabling children to internalize increasingly sophisticated forms of reasoning.

Compared with previous studies, the present findings both confirm and extend existing evidence concerning inquiry-based science learning in early childhood education. Rahardjo reported that children's engagement increases substantially when science activities encourage active exploration instead of passive observation (Rahardjo, 2019), and Izzuddin similarly found that hands-on science media strengthen children's cognitive engagement more effectively than verbal instruction alone (Izzuddin, 2021). The current findings support these conclusions but further demonstrate that sustained cognitive development depends on maintaining a coherent inquiry sequence from observation through knowledge construction. Similarly, Hasibuan and Suryanafound that experimental science activities significantly influence young children's cognitive development when repeated consistently across learning sessions (Hasibuan & Suryana, 2021). The present study extends this argument by illustrating how prediction and evidence verification function as essential cognitive mechanisms enabling children to transform concrete experiences into causal explanations. In addition, O'Connor et al., emphasized that teachers' pedagogical mediation determines the quality of scientific inquiry available to young learners (O'Connor et al., 2021), while Schmitt, Weber, Venitz, and Leuchter similarly found that preschool teachers' pedagogical content knowledge strongly predicts their willingness to diagnose and scaffold children's science learning (Schmitt et al., 2023). Consistent with this perspective, the present findings reveal that teachers' questioning strategies, rather than direct instruction, encouraged children to independently evaluate evidence and reconstruct conceptual understanding.

An important contribution of this study lies in demonstrating that the effectiveness of experimental science learning is attributable to the integration of sequential inquiry processes rather than to experimentation itself. Previous studies have generally examined experimental learning as a single instructional strategy for enhancing children's motivation or science process skills(Miladia & Muslim, 2022; Sari et al., 2021). This orientation is consistent with the broader development of STEAM education, which increasingly emphasizes the integration of scientific inquiry with higher-order and transferable competencies in early learning contexts (Febriawati et al., 2024). In contrast, the present findings indicate that children's cognitive development emerges through the cumulative interaction of observing, predicting, testing, verifying, and reflecting. Each stage provides distinct cognitive functions while simultaneously reinforcing subsequent learning processes, thereby creating a coherent pathway toward scientific reasoning. This interpretation expands current understandings of inquiry-based learning by emphasizing the importance of instructional continuity in supporting cognitive growth during early childhood.

From a pedagogical perspective, these findings imply that successful science instruction should prioritize designing inquiry experiences that systematically engage children in reasoning rather than merely demonstrating scientific phenomena. Teachers should therefore facilitate opportunities for children to formulate predictions, manipulate materials independently, discuss observations collaboratively, and justify conclusions using empirical evidence (Zamalloa et al., 2025). This recommendation is consistent with a comparative cross-national analysis by Oliver, McConney, and Woods-McConney, which found that inquiry-based science instruction is associated with stronger student outcomes across diverse educational systems, reinforcing the argument that inquiry-oriented pedagogy carries value beyond a single cultural or institutional context (Oliver et al., 2021). Such instructional practices not only strengthen children's conceptual understanding but also cultivate scientific habits of mind, including curiosity, critical observation, reflective thinking, and evidence-based reasoning. Consequently, experimental science learning should be regarded as a comprehensive pedagogical framework that supports the development of cognitive competencies essential for lifelong learning rather than solely as an instructional method for introducing scientific concepts.

The third finding concerns the way children's cognitive development was evaluated during experimental science learning. The findings show that assessment was integrated into classroom activities rather than being conducted only after the experiment had ended. Teachers observed children's responses while they were interacting with materials, making predictions, responding to experimental outcomes, and communicating their ideas. Assessment therefore provided information about children's reasoning as it developed throughout the inquiry process.

The assessment practices included observational records, anecdotal notes, children's work products, and classroom documentation. Importantly, teachers did not focus exclusively on whether children's answers were correct. They also considered how children explained phenomena, compared different outcomes, justified their predictions, and modified their explanations after encountering new evidence. One teacher explicitly stated that the focus was on how children think, ask questions, and explain what they discovered rather than simply determining whether an experiment was right or wrong.

From an interpretative perspective, these findings demonstrate that authentic assessment provides richer evidence of cognitive development than outcome-oriented evaluation because it captures children's thinking processes as they construct scientific understanding. This aligns with findings reported by Hartati and Zulminiati in a kindergarten setting, which showed that authentic, process-based assessment techniques such as observation and anecdotal records reveal aspects of children's development that standardized instruments tend to overlook (Hartati & Zulminiati, 2020). Cognitive development during early childhood is characterized by gradual conceptual restructuring rather than immediate mastery of factual knowledge. Therefore, evaluating children's ability to observe, predict, verify evidence, and revise explanations offers a more valid representation of cognitive growth than assessing isolated learning products. The findings further suggest that experimental science learning creates unique opportunities for teachers to observe higher-order cognitive processes that are often difficult to identify through conventional classroom assessment. This observation is consistent with a recent evaluation study by Sowmya and Rani (2025), which found that structured, teacher-facilitated science experiments visibly cultivated young children's curiosity and engagement in ways that were most apparent through ongoing classroom observation rather than end-of-programme measurement alone (Sowmya and Rani 2025).

These findings can be interpreted through the perspective of formative assessment, which emphasizes assessment as an integral component of learning that continuously informs both teaching and children's cognitive development. Morris, Perry, and Wardle, in a systematic review of formative assessment practices, concluded that feedback embedded within ongoing learning activities is more effective in supporting learners' progress than assessment conducted solely at the end of instruction (Morris et al., 2021). Similarly, Andrade and Brookhart emphasized that classroom assessment functions most effectively as a co-regulated process in which teachers, students, and the learning context jointly shape how understanding develops (Quintão et al., 2020). The present findings extend these perspectives by demonstrating that, within early childhood science education, formative assessment emerges naturally through experimental inquiry because children's predictions, observations, explanations, and reflections continuously generate evidence of conceptual development.

Consequently, assessment is embedded within the inquiry process itself rather than being separated from classroom learning.

The findings are also consistent with previous research emphasizing the importance of authentic assessment in early childhood education. Rahardjo reported that science learning becomes more meaningful when teachers evaluate children's inquiry processes rather than solely measuring factual understanding (Rahardjo, 2019). Likewise, Hartati and Zulminiati argued that documenting children's interactions during scientific exploration enables teachers to identify conceptual changes that are often overlooked through traditional assessment methods (Hartati and Zulminiati 2020). However, the present study extends these findings by illustrating how authentic assessment not only documents children's learning outcomes but also actively supports instructional improvement. Continuous classroom observations allowed teachers to modify learning activities, provide individualized guidance, and strengthen children's scientific reasoning according to their developmental progress. This reciprocal relationship between assessment and instruction demonstrates that evaluation functions simultaneously as evidence of learning and as a catalyst for subsequent cognitive development.

Another important contribution emerging from this study concerns the conceptualization of assessment as a pedagogical dialogue rather than an evaluative judgment. Throughout experimental activities, teachers consistently encouraged children to explain why particular phenomena occurred, compare their explanations with classmates' ideas, and reconsider conclusions after obtaining new evidence. Such dialogic assessment transformed evaluation into a reflective learning experience through which children became increasingly aware of their own reasoning processes. Rather than positioning assessment as an external judgment imposed by teachers, the evaluation process promoted children's metacognitive awareness by encouraging them to examine how their ideas changed throughout scientific investigation. This finding contributes to contemporary discussions on authentic assessment by highlighting its potential to simultaneously strengthen scientific reasoning, reflective thinking, and conceptual understanding within inquiry-based early childhood education.

Conclusion

This study concludes that experimental science learning can foster the cognitive development of children aged 5–6 years when it is implemented as a coherent inquiry-based process rather than merely as an instructional technique for introducing scientific concepts. The findings demonstrate that children’s cognitive development was supported through interconnected stages of observation, exploration, prediction, experimentation, evidence verification, and knowledge construction, which enabled them to develop causal understanding, logical reasoning, and reflective thinking through direct engagement with meaningful phenomena. The effectiveness of this process was strengthened by three interdependent pedagogical components: contextual instructional planning, inquiry-oriented classroom implementation, and continuous authentic assessment. Contextual planning provided children with familiar experiences as a foundation for exploration; teacher facilitation through questioning and guided experimentation encouraged children to examine evidence and construct explanations; and process-oriented assessment enabled teachers to document children's evolving reasoning and adapt subsequent learning experiences. These findings contribute to inquiry-based early childhood science education by emphasizing the importance of integrating experimentation, teacher facilitation, and authentic assessment within a continuous pedagogical process. Practically, the study suggests that early childhood educators should design simple contextual experiments, provide opportunities for prediction and evidence-based discussion, and assess children's reasoning processes throughout inquiry activities. However, because this study was conducted as a qualitative case study in a single early childhood education institution, its findings are context-specific and cannot be generalized broadly. Future research should therefore examine experimental science learning across multiple settings and over longer periods, including comparative, longitudinal, mixed-methods, or intervention-based designs to further examine how inquiry-oriented science experiences support children's cognitive development.

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