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The Exploring Natural Materials to Stimulate Scientific Skills in Early Childhood: The Case Study at Madre Arccuci Playgroup Kupang City

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Abstract

This study explores how natural materials can enhance scientific process skills in early childhood education within a resource limited setting in East Nusa Tenggara, Indonesia. Using a qualitative case study design, the research involved 18 children aged 5 to 6 years who participated in twelve structured and spontaneous sessions using locally sourced materials such as sand, leaves, stones, and seashells. Data were collected through classroom observations, child work documentation, and interviews with teachers. Thematic and descriptive analyses revealed substantial improvements in four targeted skills: observing, classifying, predicting, and communicating. Children also exhibited increased motivation, independence, and contextual understanding. Teacher reflections confirmed the pedagogical value of nature-based learning in creating engaging and meaningful experiences aligned with the Merdeka Curriculum. However, challenges related to material availability, pedagogical planning, and institutional support were also identified. The findings highlight the importance of local resource integration, teacher training, and systemic backing. This study contributes to the advancement of early science literacy and offers practical strategies for contextualized learning in under-resourced environments.

Keywords: Early Childhood, Natural Materials, Scientific Skills.

Introduction

The development of scientific literacy forms a fundamental basis for cultivating generations equipped with critical thinking skills and capable of contributing meaningfully within a knowledge based society. This foundation should be laid in early childhood, a phase marked by rapid brain development and heightened curiosity toward the surrounding environment (García Rodríguez et al., 2023). Known as the period of cognitive plasticity, this stage reflects children's heightened responsiveness to educational stimuli that shape their reasoning and cognitive structures (Campbell & Speldewinde, 2022).

Within this framework, the National Research Council in *A Framework for K–12 Science Education* emphasizes the importance of gradually introducing scientific practices beginning at

the preschool level. These include observing phenomena, classifying objects or data, predicting based on patterns, and formulating conclusions supported by evidence (National Research Council, 2012). Such engagement allows children to progressively develop the skills required for constructing systematic scientific arguments applicable to real world problem solving.

Globally, early science education is regarded as a strategic investment in human capital, starting from the earliest stages of life. The 2024 Global Report on Early Childhood Care and Education (ECCE) by UNESCO and UNICEF underscores the critical role of early science education in fulfilling Sustainable Development Goal (SDG) 4.2, which seeks to ensure that all children have access to quality early childhood education (UNESCO & UNICEF, 2024). However, the same report also draws attention to persistent disparities in science education access, particularly in lower middle income countries such as Indonesia, where infrastructure limitations and resource shortages remain major challenges (BPS, 2024).

One approach widely advocated by UNESCO and UNICEF is nature play, which treats natural items such as sand grains, stones, leaves, or water droplets as loose parts: elements without fixed shapes that children can manipulate based on imagination (Prins et al., 2022). These materials, easily moved, sorted, or combined, facilitate open ended exploration and enable children to pose questions, experiment freely, and construct hypotheses independently.

The potential of this method is supported by a meta ethnographic synthesis of 28 qualitative studies conducted by Prins et al. (2022). Their comprehensive review reveals that direct exposure to green environments including school gardens, yards, or urban forests diversifies children's play behavior while also extending the duration of their engagement. Additionally, these settings promote the development of conceptual scientific thinking by linking sensorimotor experiences to self formulated scientific representations.

Simultaneously, recent literature on Loose Parts Play, building upon Nicholson's early contributions and reviewed by Cankaya et al. (2023), highlights the role of material manipulation in developing executive functions. Activities such as arranging, sorting, or modifying structures enable children to practice planning, regulate attention, and control impulses. The open ended properties of materials support causal reasoning, allowing children to observe immediate physical consequences and adjust strategies based on empirical feedback.

Intervention studies from various countries consistently indicate that nature based science experiences significantly benefit young learners. For instance, Altınok et al. (2025) conducted

action research in Turkey with children aged 48 to 60 months using local environmental materials. The program led to measurable gains in core scientific process skills. These results are supported by a quasi experimental study by Savaş and Şeker (2022), which integrated nature based STEM modules into preschool curricula, showing substantial improvement in inquiry based competencies compared to the control group.

In Indonesia, research likewise demonstrates the effectiveness of natural materials in early science education. Asmah and Mustaji (2014) found that sand based exploration in a Surabaya kindergarten enhanced both science concept understanding and fine motor skills. A similar pattern was reported by Lea et al. (2018) in Palopo, indicating a strong link between natural material use and increased scientific inquiry. Arifah and Wati (2024) added to this body of evidence by demonstrating how seeds, palm fronds, and stones improved categorization and classification skills among preschool children.

Nevertheless, the majority of these studies have been limited to urban settings in Java and selected regions of Sulawesi, often focusing on specific materials. This reveals a significant gap concerning the application of nature based methods in Eastern Indonesia, particularly in the Province of East Nusa Tenggara, a region characterized by high biodiversity and complex educational challenges. Addressing this gap is vital to adapting pedagogical strategies that align with both local ecosystems and cultural contexts.

The Merdeka Curriculum recognizes early childhood education institutions (PAUD) as key actors capable of designing learning that is contextualized to local realities. It promotes project based learning and encourages the use of learning resources rooted in local culture and nature including sand, stones, leaves, and water (Kemendikdasmen, 2023). These strategies aim to enhance the relevance of education, stimulate discovery and build ecological awareness in children from an early age.

However, national data from the Central Bureau of Statistics (BPS) reveals a less favorable picture in some regions. In Kupang Regency, for instance, the gross enrollment rate (GER) for PAUD is 31.3%, below the provincial average of 34.4% (BPS, 2024). This statistic highlights limited access to early childhood education and suggests that even fewer children are exposed to contextual, nature based learning experiences. The low GER reflects infrastructure gaps, a shortage of trained personnel, and limited availability of relevant local materials.

These challenges indicate three interrelated problems. First, research on the use of natural materials in the Province of East Nusa Tenggara remains fragmented and sporadic. Second, while the Merdeka Curriculum emphasizes contextual learning, the integration of nature based content is not yet systematically embedded in planning, resource provision, or assessment frameworks. Third, there is limited information on educators' perceptions, including their views on the benefits, constraints, and support required to implement such approaches.

In response to these issues, this study aims to explore how natural materials can be used to develop scientific competencies in children aged 5–6 years at Madre Arccuci Playgroup in Kupang City, East Nusa Tenggara Province. Specifically, the study pursues three objectives: (1) mapping local resources by identifying natural materials and establishing usage strategies for guided and spontaneous activities; (2) measuring learning impacts by tracking changes in four scientific skills: observing, classifying, predicting, and communicating; (3) exploring educators' perspectives on opportunities, implementation challenges and systemic support aligned with the Merdeka Curriculum.

The study's findings are expected to contribute to the growing body of knowledge on early childhood science education in underdeveloped regions, particularly in East Nusa Tenggara Province. The results aim to inform education stakeholders by providing practical recommendations for integrating nature based learning into curriculum planning, thereby enriching the implementation of the Merdeka Curriculum and bridging existing equity gaps in foundational science education.

Methodology

This study adopted a qualitative case study approach to investigate how natural materials support the development of scientific skills among early childhood learners aged five to six at Madre Arccuci Playgroup in Kupang City, East Nusa Tenggara Province, Indonesia. The approach was chosen to enable an in-depth understanding of authentic learning experiences situated within a specific ecological and cultural context. A total of eighteen children, comprising nine boys and nine girls, participated in twelve learning sessions over the course of four weeks. During this period, they engaged in a range of structured and spontaneous activities using natural materials readily available in the local environment, including sand, stones, leaves, and seashells. Additional data were collected through semi-structured interviews with four

classroom teachers and the head of the institution to gain insight into pedagogical strategies and the broader contextual factors influencing classroom practices.

Triangulation was established through the use of multiple data sources and methods, such as direct classroom observations, field notes, samples of children's work, and interview transcripts. Thematic analysis was conducted following the Braun and Clarke (2006) framework to identify recurring themes related to skill development, engagement patterns, and interactions with the learning environment. NVivo software was utilized to assist in the systematic coding and categorization of qualitative data, allowing for greater consistency and depth in theme identification. In addition, a four-point scale was applied to evaluate changes in student performance before and after the intervention. Qualitative narratives from teacher reflections and institutional perspectives further enriched the analysis. Ethical protocols were upheld by securing informed consent from parents and ensuring that the children's well being and voluntary participation were prioritized throughout the study. This comprehensive methodological design provided a detailed exploration of how nature based learning experiences contribute to foundational scientific thinking in alignment with the Merdeka Curriculum's emphasis on contextual, exploratory, and child centered learning.

Research Findings

Thematic and Quantitative Analysis of Scientific Process Skill Development

To analyze the development of scientific process skills in early childhood, this study employed NVivo 12 Plus software to systematically code and organize qualitative data derived from twelve field observation journals, five semi-structured interview transcripts, and forty-eight pieces of children's work documentation. In alignment with the research objectives, four principal nodes were established, namely observing, classifying, predicting, and communicating. Each of these nodes comprised several sub-nodes that reflected children's behaviors, such as sensory perception, attribute-based grouping, anticipatory reasoning, and both verbal and symbolic expression. The coding process yielded a total of 221 references, which were evenly distributed across all sources.

Frequency Distribution of Scientific Skills

The frequency analysis indicated that observing was the most frequently referenced skill (n = 67), followed by classifying (n = 59), communicating (n = 52), and predicting (n = 43). The

consistency of these references, with coverage ranging from 61% to 84% across the data sources, suggests that all four basic scientific skills emerged regularly throughout the learning sessions.

This pattern was reinforced by quantitative data, which reflected an increase in the average scores of children's scientific skills before and after the intervention, as summarized below:

Table 1. Average Development of Children's Basic Scientific Process Skills Before and After the Intervention

Skill Aspect	Pre-Intervention	Post-Intervention
Observing	2.1	3.8
Classifying	2.3	4.0
Predicting	1.9	3.5
Communicating Findings	2.0	3.7

Note: 4-point scale, where 1 = not evident, 2 = occasionally evident, 3 = frequently evident, 4 = consistently evident.

These score increases indicate substantial progress across all measured areas. The most prominent growth was observed in classifying and observing, followed by communicating and predicting.

Thematic Findings by Skill Category

Observing

Children demonstrated enhanced sensory awareness when interacting with natural materials. During sand and water exploration, for instance, they employed a broader range of descriptive vocabulary, including terms such as "rough," "smooth," "large," and "different." This expansion reflects both improved observation and increased mastery of descriptive language.

Classifying

Children actively grouped objects based on color, size, and shape. When arranging leaves or sorting stones, they exhibited logical thinking and consistency in classification. The data also revealed that observing and classifying often co-occurred, suggesting a close relationship between sensory perception and early analytical reasoning.

Predicting

Although less frequently referenced, children's predictive reasoning showed notable conceptual depth. They began to articulate expectations regarding outcomes prior to conducting actions, such as stating, "if water is added, it will fall," which reflects emerging causal and anticipatory thinking.

Communicating

Children expressed their scientific understanding through both verbal descriptions and symbolic representations. Teachers observed that children became increasingly expressive, often using drawings, patterns, or object arrangements to convey their interpretations. This behavioral shift signifies a growing capacity for scientific communication at an early age.

Scientific Indicators Derived from Exploratory Activities

Scientific behaviors were also observed through children's interactions with specific natural materials. The following table summarizes their activities and the related scientific indicators:

Table 2. Examples of Children's Work and Observed Scientific Indicators in Exploratory Activities

Type of Material	Children's Activities	Observed Scientific Indicators
Sand and Water	Building towers, recording changes	Prediction, observation, communication
Leaves and Gravel	Grouping by shape and color	Classification, logical reasoning, symbolizing
Seashells and Seeds	Creating symmetrical patterns	Shape recognition, visual balance

These activities enabled children to construct conceptual understanding through direct experimentation and adaptive revision. When their constructions collapsed, they adjusted their approaches, revealing problem-solving behavior and perseverance.

Teachers' Reflections on Pedagogical Impact

Semi-structured interviews with four teachers and the head of the early childhood unit revealed a shared perspective regarding the positive impact of nature-based learning. Teachers reported that children appeared more enthusiastic, focused, and independent during the activities. They also noted that the use of familiar materials, such as leaves, stones, or water, made learning experiences more relatable and engaging. Teachers' reflections are summarized below:

Table 3. Teachers' Perspectives on the Impact of Nature-Based Learning

Observed Aspect	Teacher Statement	Impact Category
Children's Interest	"Children seemed more excited when playing with leaves, stones, and water."	Emotional – Motivational
Level of Exploration	"They asked more questions, tried new things, and were not afraid to experiment."	Cognitive – Exploratory
Contextual Relevance	"The materials they used were part of their everyday surroundings."	Contextual – Social Relevance
Classroom Atmosphere	"Activities felt livelier, children were less bored and more focused."	Learning Environment – Interactive

In addition, teachers observed that nature-based activities contributed to a more interactive and engaging classroom environment. Children became emotionally invested and showed increased confidence in expressing their thoughts and discoveries.

Implementation Challenges and Recommended Actions

Despite the evident advantages, teachers encountered several challenges during the implementation of nature-based learning. These challenges and proposed solutions are summarized in the table below:

Table 4. Teachers' Challenges and Needs in Implementing Nature-Based Learning

Challenge Aspect	Description of the Issue	Proposed Solutions
Availability of Materials	"During the dry season, dried leaves disappear and sand becomes difficult to obtain."	Material storage strategies or alternative catalogs
Scientific Learning Design	"Not all teachers know how to link natural materials with scientific concepts."	Science-oriented pedagogical training
Teacher Preparedness	"We still need practical lesson plans that explicitly use natural materials."	RPPH guides and localized activity modules
Institutional Support	"Individual motivation is not sufficient. We need support from the school."	Institutional commitment and regular supervision

Teachers emphasized that long-term success depends on structural support from the school, including resource provision, leadership commitment, and continuous academic guidance. Without these factors, the integration of nature-based learning risks remaining incidental rather than systemic.

Synthesis of Analytical Findings

Visualizations generated through NVivo, such as treemaps and cluster analyses, reinforced the dominance of observing and classifying as foundational scientific skills. Teacher narratives consistently emphasized increases in curiosity, independence, and emotional engagement among children. These findings support the conclusion that nature-based learning is pedagogically effective, contextually appropriate, and well-suited to the developmental characteristics of early childhood learners.

Discussion

The implementation of structured and spontaneous exploratory activities using natural materials over a four-week period resulted in measurable growth across all four targeted scientific process skills. Children aged 5 to 6 years demonstrated substantial improvement in observing, classifying, predicting, and communicating, as indicated by both qualitative observations and post-intervention assessments. These findings affirm that natural materials,

when used contextually, can serve as effective stimuli for fostering scientific thinking in early learners (Altınok et al., 2025; Savaş & Şeker, 2022).

Observational data revealed a marked increase in the use of descriptive language, sensory awareness, and reflective articulation during activities involving sand, water, stones, and leaves. Children exhibited greater attention to physical properties such as texture, weight, and shape, and consistently used comparative vocabulary to express these observations. This behavioral pattern suggests that hands-on interaction with natural materials enriched not only perceptual sensitivity but also cognitive verbalization, an essential element in the observing dimension of scientific skills (García Rodríguez et al., 2023).

The skill of classifying was developed as children began sorting objects based on color, size, or form. During leaf arrangement or stone grouping activities, learners exhibited analytical reasoning by organizing materials logically and consistently. Moreover, the frequent co-occurrence of observing and classifying behaviors suggests a synergistic relationship between sensory engagement and early categorization skills. This aligns with Prins et al. (2022), who emphasized the integration of sensorimotor experiences into children's conceptual frameworks.

Although less frequently demonstrated, predicting showed promising development, especially when children made anticipatory statements about the outcomes of their actions. For example, expressions such as "if we add water, the sand will fall" indicate emerging causal reasoning and hypothesis formulation. These instances demonstrate children's growing capacity to foresee results based on prior experiences, which is fundamental to scientific inquiry (Johnstone et al., 2022).

Communicative competence was also enhanced during the intervention, as children conveyed their observations using both verbal explanations and symbolic representations such as drawings, object patterns, or physical arrangements. This ability to translate physical interactions into expressive forms is a foundational component of scientific communication. Teachers noted that children became increasingly confident in expressing ideas and interpreting phenomena, which reflects growing autonomy in constructing and sharing knowledge (Handayani et al., 2019).

Natural material exploration allowed children to construct understanding through experimentation and self-correction. When faced with collapsing structures or unstable arrangements, children revised their strategies and rebuilt using new approaches. These iterative

behaviors point to the development of problem-solving abilities and perseverance. Such findings are consistent with Cankaya et al. (2023), who reported that manipulating open-ended materials supports the development of executive functions including planning, focus, and impulse control. This type of trial-and-error learning is echoed in Lerer et al. (2016) research, which demonstrated how children develop physical intuition through interactions with unstable structures such as block towers. Their study highlights the cognitive processes involved in predicting structural failure and adjusting strategies, which closely parallels the children's actions with sand and stones in this study.

The project-based use of local materials also contributed to spatial reasoning and pattern recognition, particularly during activities involving the creation of symmetrical arrangements using seeds, stones, or seashells. These tasks engaged children in visual balancing and geometric awareness, reinforcing the relationship between motor coordination and scientific thought. This finding aligns with Skothou and Trapali's (2025) research on teaching scientific concepts such as magnetism to preschool children through ICT-enhanced play, which showed that conceptual science learning can emerge effectively through hands on, exploratory methods, even when applied to abstract domains. The results support the Merdeka Curriculum's emphasis on contextual learning and learner autonomy. The results support the Merdeka Curriculum's emphasis on contextual learning and learner autonomy (Kemendikdasmen, 2023; Netsopa & Nakhunsong, 2024).

Teachers' reflections corroborated the observational data by highlighting the motivational and emotional impact of nature-based activities. The use of familiar, readily available materials appeared to enhance children's emotional connection to the learning environment. According to the teachers, children displayed excitement and enthusiasm during these activities, reinforcing the view that emotional engagement is critical for effective early learning (Wolff & Skarstein, 2020).

The activities also promoted exploration and independence. Teachers observed that children asked more questions, took initiative in problem-solving, and were willing to experiment with various combinations of materials. This behavior reflects the development of scientific dispositions such as curiosity, persistence, and reflective thinking, which are essential traits in lifelong learning and inquiry (Campbell & Speldewinde, 2022).

The contextual relevance of natural materials strengthened the learning experience by connecting classroom activities to children's everyday lives. Materials such as leaves, stones, and water were already familiar to the children through outdoor play, which made the transition into learning contexts more seamless and meaningful. This reinforces the role of locally grounded content in creating culturally resonant and ecologically informed learning experiences (Aprianti et al., 2024).

Classroom dynamics improved significantly during the intervention. Teachers reported a more lively and interactive atmosphere, with children demonstrating greater focus and reduced boredom. Nature-based tasks, in contrast to conventional workbook activities, encouraged participation and sustained engagement. These outcomes suggest that integrating natural materials into early childhood education can transform learning environments into spaces that are both stimulating and inclusive (Bae et al., 2022).

Despite these advantages, the study identified several practical challenges that hinder the broader implementation of nature-based learning. Seasonal variations affected material availability, particularly during dry months when leaves and sand became scarce. Teachers recommended developing material storage systems or alternative material catalogs that ensure consistent access to learning resources throughout the year. Teachers also expressed a need for clearer guidance on linking natural materials to scientific concepts. Many found it challenging to formulate guiding questions, design simple experiments, or assess inquiry-based processes. This highlights the importance of professional development programs that focus on science-oriented pedagogical strategies, particularly in under-resourced early childhood settings (Saraswati, 2021).

A further constraint concerned the lack of practical planning tools, such as Daily Learning Implementation Plans (RPPH) or sample activity modules. Teachers indicated that the absence of structured references limits the systematic integration of nature-based activities into formal curricula. This observation underscores the need for instructional resources that are both adaptable and context-sensitive (Asmah & Mustaji, 2014).

Finally, systemic support from educational institutions remains critical. Teachers emphasized that individual motivation is not sufficient for sustainable implementation. Institutional commitment, in the form of leadership support, budget allocation, resource provision, and academic supervision, is necessary to embed nature-based learning within school

culture. These findings affirm the arguments of Prins et al. (2022), who identified institutional readiness as a key factor in the success of nature-oriented educational initiatives

Limitations and Implications for Future Research

This study presents several limitations that should be addressed in subsequent research.

1. First, the investigation was confined to a single early childhood institution with a relatively small sample of 18 children. This limited scope may restrict the generalizability of the findings to other demographic or geographic settings. Expanding future studies to include diverse contexts and larger populations would enhance the representativeness of the results.
2. Second, the qualitative case study design prioritized depth over breadth and does not permit causal inferences. Although the findings provide rich contextual insights, incorporating mixed-method or quasi-experimental approaches could offer more robust conclusions regarding the effects of nature-based learning.
3. Third, the primary sources of data relied heavily on teacher observations and researcher interpretation, which may be influenced by subjective bias. Integrating additional instruments, such as video documentation, structured child interviews, or standardized observation tools, would strengthen data validity.
4. Further inquiry should also explore longterm impacts on scientific dispositions, ecological awareness, and higher-order thinking. Investigating institutional frameworks and teacher preparation models would contribute to the sustainability of nature-based approaches in early education

Conclusion

The findings of this study confirm that structured, contextual use of natural materials can significantly promote the development of basic scientific process skills in early childhood learners. By engaging with sand, stones, leaves, and seashells, children demonstrated notable progress in observation, classification, prediction, and communication. These improvements were accompanied by heightened emotional engagement, cognitive autonomy, and contextual awareness.

Teacher reflections reinforced the educational relevance of nature-based learning in fostering discovery-oriented, culturally grounded, and participatory classroom environments.

Nonetheless, challenges such as seasonal material limitations, gaps in pedagogical design, and inadequate institutional support remain prevalent.

To ensure the systematic integration of this approach, early childhood institutions must adopt supportive measures including the provision of teacher training, the development of locally tailored instructional resources, and consistent leadership involvement. Addressing these conditions would support the full implementation of the Merdeka Curriculum and expand access to foundational science education in underserved areas.

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