



Design and Models of Natural Materials as Realistic Educational Toys (APE-R) for Early Childhood Education in School environments

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ABSTRACT

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This study aims to examine the design characteristics of Realistic Educational Play Tools (APE-R) based on natural materials and to synthesize their implications for early childhood development. The study focuses on how authentic natural materials can be transformed into meaningful, contextual, and developmentally appropriate play-based learning resources. A Systematic Literature Review (SLR) was conducted by analyzing relevant scientific articles published between 2021 and 2026. Literature was identified through systematic searches of Scopus, Web of Science, and Google Scholar using keywords related to natural materials, educational play tools, play-based learning, nature-based learning, and early childhood education. The selected studies were analyzed through qualitative thematic synthesis involving data condensation, thematic categorization, data display, and verification. The synthesis identifies five core characteristics of APE-R: authenticity, flexibility, multisensory engagement, contextuality, and sustainability. The model supports multiple developmental domains, including cognitive, language, fine- and gross-motor, social-emotional, creative, sensory, early science, early numeracy, ecological awareness, and approaches to learning. The study contributes a conceptual framework positioning APE-R as a holistic pedagogical model that integrates natural materials, open-ended play, contextual learning, teacher facilitation, and developmental objectives. The framework provides a foundation for future empirical validation and practical development of nature-based educational play resources.

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INTRODUCTION

Early childhood education is a critical social investment because experiences during the early years shape children's cognitive, language, social-emotional, motor, creative, and environmental development. Play provides a

natural context through which children explore, communicate, construct knowledge, and develop relationships. Evidence from research on learning through play and game-based learning indicates that playful experiences can strengthen engagement, motivation, interaction, and learning outcomes (McMahon et al., 2022; Alotaibi, 2024). For society, therefore, improving the quality and accessibility of play-based learning is important because it can support children's development while creating learning opportunities that are meaningful and responsive to their environments. Educational practices that connect children with real materials may also encourage curiosity and active participation. Consequently, developing accessible, contextual, and developmentally appropriate educational play resources is not merely a classroom concern but an important educational and social priority for communities.

A general problem is that early childhood learning resources are designed around predetermined functions, limiting opportunities for children to manipulate, reinterpret, and use materials in different ways. Conventional educational toys may also be less connected to children's immediate environments, reducing opportunities to relate classroom experiences to familiar objects and everyday situations. Such limitations are important because children learn effectively through exploration and experience. Research on nature play shows that natural environments can provide richer affordances for exploration, social interaction, and engagement than more restricted play settings (Prins et al., 2022; Johnstone et al., 2022). When learning resources do not support these characteristics, children may have fewer opportunities to develop independence, creativity, problem-solving, and contextual understanding. This challenge highlights the need to reconsider how educational play materials are designed and connected with children's social environments effectively.

In school settings, the use of natural materials as educational resources is relevant because materials such as stones, leaves, seeds, twigs, sand, wood, bamboo, and clay are often accessible within children's surroundings. However, their presence does not automatically make learning meaningful; teachers must transform these materials into purposeful play experiences through appropriate design. Studies show that natural and non-natural materials offer diverse play affordances, while teachers' support influences how children explore and extend their play (Sahetapy et al., 2025; Annuar et al., 2025). Indonesian studies have also explored environmental materials and natural-material-based learning activities for early childhood education (Dewi, 2023). These developments indicate an opportunity for schools to use locally available materials, but they also reveal the need for a clearer framework linking material characteristics, learning objectives, play design, and developmental outcomes.

Research has established the value of nature-based learning and play for children's development. Systematic reviews indicate that nature-based early childhood education can support social, emotional, and cognitive development, while nature play provides opportunities for exploration, engagement, and meaningful interaction (Johnstone et al., 2022; Prins et al., 2022). Studies have examined natural loose parts, environmental materials, and creative activities, demonstrating their potential to support multiple developmental domains (Yuhana & Nurlinda, 2026). However, this literature addresses individual activities or developmental outcomes. Consequently, the literature provides evidence for the usefulness of natural materials but offers less integration of their design characteristics into a unified educational play model. This limitation is important because schools need guidance not only on whether natural materials are beneficial, but also on how they can be designed as learning tools.

Research on game-based and experiential learning further demonstrates that participation and direct experience can contribute to meaningful learning. Game-based learning research reports positive effects on engagement and learning, while experiential learning emphasizes the importance of embodied interaction with the environment (Alotaibi, 2024; Lebert & Vilarroya, 2024). Research on educational play tools and nature play suggests that learning outcomes depend on activity design and pedagogical facilitation (Dewi, 2023; Puspita et al., 2025). Nevertheless, previous studies have rarely brought together natural-material affordances, realistic and contextual learning, open-ended play, multisensory experience, teacher scaffolding, and developmental objectives within one conceptual framework. This gap matters because fragmented findings make it difficult to formulate a model for schools to design natural-material-based play. This perspective highlights context, teacher competence, and children's agency across contexts.

The state of the art of this study lies in proposing Realistic Educational Play Tools (APE-R) as a conceptual model that positions natural materials not simply as substitutes for manufactured toys, but as authentic, flexible, multisensory, contextual, collaborative, and sustainable learning resources. It emphasizes the relationship among material characteristics, children's exploratory activity, teacher facilitation, learning objectives, and developmental outcomes. Its novelty is the systematic organization of these elements into a coherent framework for early childhood educational play. APE-R therefore seeks to bridge natural-material affordances with realistic learning principles and developmentally appropriate pedagogy. It provides a basis for designing and evaluating natural-material-based play in schools while maintaining children's autonomy, engagement, and connection with everyday environments. The model organizes evidence into a conceptual structure for empirical studies, classroom implementation, teacher development, and assessment for schools.

This study addresses how natural materials can be systematically designed as Realistic Educational Play Tools (APE-R) and what developmental implications may emerge in schools. It argues that APE-R can function as a pedagogical framework when authentic materials are intentionally matched with developmental objectives, open-ended play activities, contextual experiences, teacher scaffolding, and opportunities for collaboration. It asks two questions: what are the design characteristics of natural materials as APE-R, and what are the implications of implementing the model for early childhood development? Through a systematic synthesis, the study contributes a conceptual foundation for connecting play materials, pedagogical design, and holistic developmental outcomes. The framework may support teachers and schools in developing accessible, meaningful, and child-centered learning experiences. The framework also supports future validation and adaptation across diverse school contexts, connecting conceptual development with practical improvement and educational communities.

RESEARCH METHODS

This study employed a qualitative research design using a Systematic Literature Review (SLR) to identify, analyze, and synthesize studies on natural materials as Realistic Educational Play Tools (APE-R) for early childhood education. A qualitative approach was selected because the study aimed to interpret concepts, patterns, pedagogical principles, and developmental implications rather than statistically measure relationships. The SLR approach was appropriate for integrating findings from diverse studies on play-based and nature-based learning. Previous research indicates that nature-based early childhood education can support children's social, emotional, and cognitive development (Johnstone et al., 2022; Prins et al., 2022). Research on game-based learning also demonstrates its potential to support meaningful learning experiences in early childhood (Alotaibi, 2024; Hibana et al., 2024).

The research setting was the literature environment represented by scientific publications concerning early childhood education, natural materials, educational play tools, and play-based learning. No physical school was selected because the units of analysis were published studies. Data were collected through systematic searches of Scopus, Web of Science, and Google Scholar using combinations of keywords such as *natural materials*, *educational play tools*, *play-based learning*, *nature-based learning*, *early childhood education*, and *kindergarten*. Articles were included if they were published between 2021 and 2026, available in full text, published in scientific journals, and relevant to the research focus.

Studies demonstrate that natural materials provide diverse play affordances and support meaningful learning experiences among preschool children (Dankiw et al., 2023; Deng et al., 2025).

Data were collected through systematic document analysis of the selected articles. Relevant information was extracted regarding material characteristics, APE design, learning activities, pedagogical approaches, and developmental outcomes. Data analysis followed four stages: data condensation, data display, conclusion drawing, and verification. During data condensation, relevant findings were selected, coded, and categorized according to the research objectives. The data were then displayed thematically to identify similarities, differences, and relationships across studies. Conclusions were subsequently formulated and verified by comparing findings across the selected literature. Research on natural-material-based learning and educational play tools shows that concrete and open-ended materials can facilitate children's engagement, creativity, and conceptual learning (Dewi, 2023; Matafwali & Mofu, 2023).

RESULTS AND DISCUSSION

Results

Design Characteristics of Natural Materials as Realistic Educational Play Tools (APE-R) for Early Childhood Education

The synthesis of studies published between 2021 and 2026 indicates that natural materials have distinctive characteristics that make them suitable for development as Realistic Educational Play Tools (APE-R) in early childhood education. Unlike conventional toys with predetermined forms and functions, natural materials are flexible and open-ended, allowing children to explore multiple possibilities according to their imagination, interests, and learning experiences. Natural environments and materials provide rich opportunities for exploration, engagement, social interaction, and cognitive development (Prins et al., 2022; Johnstone et al., 2022). Natural objects such as stones, sand, leaves, twigs, seeds, wood, bamboo, coconut shells, and clay can also connect classroom learning with children's immediate environments and everyday experiences. Their educational value therefore depends less on material sophistication than on their capacity to facilitate meaningful and contextual play.

Interaction with natural materials enables children to observe, touch, compare, classify, arrange, construct, and experiment through direct experience. Research demonstrates that natural and non-natural materials provide diverse play affordances that encourage exploratory and meaningful activities (Chookah et al., 2023; Dankiw et al., 2023). Accordingly, APE-R can be conceptualized through the integration of play-based learning, experiential learning, and nature-based learning. Natural materials provide concrete and multisensory experiences

through which children construct knowledge while manipulating and exploring objects. Experiential learning emphasizes direct experience, while play-based learning promotes active participation and meaningful engagement (Lebert & Vilarroya, 2024; Parker et al., 2022). Thus, APE-R positions children as active learners and teachers as facilitators who extend exploration through appropriate guidance and scaffolding.

A further finding concerns the open-ended character of natural materials. A single material can support different learning objectives depending on how teachers design the activity. Stones, for example, can be used for counting, sorting, pattern recognition, shape identification, construction, motor activities, and collaborative games, while leaves, seeds, twigs, and sand can be integrated into science, art, language, mathematics, and social activities. Research on natural loose parts indicates that seeds and leaves can support cognitive, motor, language, social-emotional, creative, and ecological development when incorporated into appropriately designed play activities (Yuhana & Nurlinda, 2026; Fajrie et al., 2024). Therefore, APE-R should be viewed as a flexible pedagogical resource rather than a fixed educational product.

The synthesis further shows that the effectiveness of APE-R depends on the alignment among material characteristics, learning objectives, developmental levels, activity design, and the learning environment. Natural materials alone do not automatically produce meaningful learning outcomes; their educational potential emerges when teachers intentionally organize developmentally appropriate activities and provide opportunities for exploration, interaction, and collaboration. Based on the reviewed evidence, five principles characterize APE-R design: authenticity, flexibility, multisensory engagement, contextuality, and safety and sustainability. These principles enable children to interact with real objects, use materials in multiple ways, engage their senses, connect play with everyday life, and develop environmental awareness (Prins et al., 2022; Samad et al., 2025). The collaborative dimension is also important because interaction with peers and adults can strengthen communication, cooperation, and knowledge construction (De Felice et al., 2022; Fajrie et al., 2025).

The empirical foundation for these characteristics is summarized in Table 1. The reviewed studies consistently demonstrate that natural environments, natural loose parts, educational play tools, and play-based approaches can support children's engagement, exploration, creativity, cognitive development, motor development, and social interaction. The evidence also indicates that teacher facilitation and activity design influence how effectively natural materials contribute to children's development (Smedsrud et al., 2024; Fox et al., 2023). Therefore, the findings presented in Table 1 provide an empirical basis for conceptualizing APE-R as an integrated pedagogical model rather than merely a

collection of natural-material toys. In this framework, the educational value of APE-R emerges from the interaction among authentic materials, open-ended design, multisensory experiences, contextual learning, collaborative play, and purposeful teacher facilitation.

Table 1. Empirical Basis for the Development of the APE-R Concept

No.	Researcher(s)	Research Title	Method	Main Findings Relevant to APE-R
1	Prins et al. (2022)	<i>Nature Play in Early Childhood Education: A Systematic Review and Meta-Ethnography of Qualitative Research</i>	Systematic Review and Meta-Ethnography	Nature play provides rich affordances for exploration, engagement, social interaction, creativity, and children's development. Natural environments offer authentic contexts for play and learning.
2	Johnstone et al. (2022)	<i>Nature-Based Early Childhood Education and Children's Social, Emotional and Cognitive Development: A Mixed-Methods Systematic Review</i>	Mixed-Methods Systematic Review	Nature-based education is associated with positive social, emotional, and cognitive development and provides opportunities for meaningful engagement with natural environments.
3	Alotaibi (2024)	<i>Game-Based Learning in Early Childhood Education: A Systematic Review and Meta-Analysis</i>	Systematic Review and Meta-Analysis	Game-based learning can strengthen children's engagement, motivation, and learning outcomes, supporting the pedagogical basis for play-oriented APE-R.
4	Smedsrud et al. (2024)	<i>Early Childhood Teachers' Support of Children's Play in Nature-Based Outdoor Spaces: A Systematic Review</i>	Systematic Review	Teacher support and scaffolding are important in extending children's exploration, interaction, communication, and problem-solving during nature-based play.

5	Parker et al. (2022)	<i>Learning Through Play at School – A Framework for Policy and Practice</i>	Conceptual Framework	Learning through play provides opportunities for active engagement, meaningful learning, interaction, and development when appropriately integrated into educational practice.
6	Yuhana & Nurlinda (2026)	<i>Seeds, Leaves, and Learning: A Literature Review on the Use of Natural Loose Parts as Educational Play Tools in Early Childhood Education</i>	Literature Review	Natural loose parts such as seeds and leaves can support cognitive, motor, language, social-emotional, creative, and ecological development through open-ended play.
7	Fajrie et al. (2024)	<i>Natural Material-Based Art Learning Model Increases Aesthetic Experiences in Early Childhood</i>	Educational Model Study	Natural materials can be integrated into structured and creative learning activities to enrich children's aesthetic experiences and active participation.
8	Dewi (2023)	<i>Educative Game Tools Based on Environmental Materials in Overcoming Learning Problems in Early Childhood Education Programs</i>	Educational Development Study	Environmental materials can be developed into educational play tools that provide accessible and contextual learning experiences for young children.

The findings in Table 1 reveal a consistent pattern: the educational potential of natural materials emerges from the interaction among material affordances, children's active exploration, pedagogical design, and teacher facilitation. This shifts the perspective from viewing natural materials merely as inexpensive or environmentally friendly resources toward recognizing them as meaningful learning media (Chookah et al., 2023; Dewi, 2023). The synthesis identifies five dimensions distinguishing APE-R from conventional educational toys: authenticity, flexibility, multisensory engagement, contextuality, and sustainability. These dimensions enable children to interact with real objects, explore multiple uses, engage in sensory experiences, connect learning with everyday contexts, and develop environmental awareness (Johnstone et al., 2022;

Yuhana & Nurlinda, 2026). Teacher facilitation is also essential, as teachers create appropriate environments, provide materials, observe children's interests, ask stimulating questions, and provide scaffolding to extend exploration and interaction (Smedsrud et al., 2024; Fox et al., 2023).

The synthesis further reveals a significant research gap. Existing studies have examined nature-based learning, natural loose parts, game-based learning, educational play tools, and natural-material-based activities, but limited attention has been given to integrating these elements into a specific conceptual framework of Realistic Educational Play Tools (APE-R). The novelty of this study lies in synthesizing authentic natural materials, contextual learning, open-ended play, multisensory engagement, teacher scaffolding, collaboration, and developmental objectives into an integrated pedagogical framework. Accordingly, APE-R is conceptualized not merely as an educational toy but as a pedagogical framework for designing contextual, exploratory, multisensory, collaborative, and sustainable learning experiences. This conceptualization extends research on nature play and game-based learning by positioning natural materials within a coherent educational design framework (Prins et al., 2022; Alotaibi, 2024). Thus, APE-R provides a potential contribution to early childhood education by connecting children's everyday experiences with structured learning objectives while preserving the essential characteristics of play.

Implications of Implementing the Natural Materials-Based Realistic Educational Play Model (APE-R) for Early Childhood Development

The synthesis indicates that implementing the Realistic Educational Play Model (APE-R) with natural materials has multidimensional implications for early childhood development. Materials such as stones, sand, leaves, twigs, seeds, wood, bamboo, and clay provide direct interaction with authentic objects and allow children to explore multiple possibilities through open-ended play. Nature-based play offers rich opportunities for exploration, engagement, creativity, social interaction, and learning (Prins et al., 2022; Johnstone et al., 2022). Similarly, game-based learning can enhance children's engagement and learning experiences (Alotaibi, 2024; Parker et al., 2022). Thus, APE-R can be understood as a pedagogical approach that transforms natural materials into meaningful learning experiences.

The cognitive implications of APE-R emerge through observation, classification, comparison, sequencing, counting, pattern recognition, construction, and simple problem-solving. Direct manipulation of natural materials enables children to connect new experiences with prior knowledge while encouraging divergent thinking and creativity. Natural-material-based learning and natural loose parts can support cognitive development, creativity,

and active engagement (Fajrie et al., 2024; Yuhana & Nurlinda, 2026). APE-R also supports language, social-emotional, and creative development because collaborative activities encourage children to communicate, negotiate roles, share materials, resolve disagreements, and construct objects together. Social interaction supports knowledge development through communication with peers and adults, while open-ended materials encourage imagination and self-expression (De Felice et al., 2022; Fajrie et al., 2025).

APE-R further provides opportunities for fine-motor, gross-motor, sensory, early science, and early numeracy development. Activities such as threading seeds, arranging twigs, molding clay, collecting natural objects, comparing textures, counting stones, and creating patterns require coordination, perception, attention, and physical movement. Research on sensory play with natural materials and natural-material-based mathematics supports their potential for developing fine-motor abilities and early mathematical understanding (Sianturi et al., 2026; Sudarti et al., 2025; Hifza et al., 2023). The ecological dimension is also important because repeated interaction with natural environments can strengthen children's connection to nature and encourage responsible attitudes toward their surroundings (Johnstone et al., 2022; Dankiw et al., 2023). Consequently, ecological awareness can be embedded within everyday play rather than treated as a separate learning topic.

The specific developmental implications identified from the literature are summarized in Table 2. The table demonstrates that APE-R can support a broad range of developmental indicators, including cognitive, language, motor, social, emotional, creative, sensory, scientific, mathematical, ecological, and learning-related competencies. The examples illustrate how ordinary natural materials can be transformed into purposeful learning activities when teachers align materials and activities with children's developmental objectives. Therefore, the educational value of APE-R depends not simply on the availability of natural materials but on the quality of the play activities, pedagogical design, and teacher facilitation through which children interact with those materials.

Table 2. Indicators of the Implications of the Realistic Educational Play Model (APE-R)			
Developmental Dimension	Developmental Indicators	Implementation Through Nature-Based APE-R	Expected Developmental Outcomes
Cognitive Development	Observation, classification, comparison, pattern recognition, problem-solving, logical reasoning	Sorting stones by size; creating patterns with leaves and seeds; comparing sand or soil	Improved logical reasoning, creativity, critical thinking, and problem-solving

Language Development	Communication, vocabulary, storytelling, questioning, responding	Describing the shape, color, texture, and function of natural materials	Improved vocabulary, communication, and emergent literacy
Fine-Motor Development	Hand-eye coordination, grasping, pinching, threading, manipulation	Threading seeds; arranging twigs; making leaf collages; molding clay	Improved fine-motor coordination and manipulation
Gross-Motor Development	Balance, coordination, agility, movement control	Collecting materials; outdoor exploration; movement games using natural materials	Improved balance, coordination, and physical control
Social Development	Collaboration, sharing, communication, leadership, conflict resolution	Cooperative construction and group play using stones, sand, twigs, or wood	Improved cooperation, interaction, communication, and leadership
Emotional Development	Self-regulation, confidence, independence, persistence	Completing individual or group projects using natural materials	Increased confidence, persistence, independence, and emotional regulation
Creativity Development	Imagination, innovation, creative production	Creating animals, houses, vehicles, patterns, or artwork from open-ended materials	Enhanced imagination, divergent thinking, and creativity
Sensory Development	Recognition of texture, color, aroma, shape, temperature, and weight	Exploring leaves, sand, stones, bark, seeds, and clay	Improved sensory integration and observation
Early Science Literacy	Observation, identification, investigation, comparison	Observing leaf changes; comparing soil textures; exploring floating and sinking	Enhanced scientific curiosity and basic inquiry skills
Early Numeracy	Counting, sequencing, measuring, pattern and shape recognition	Counting stones; ordering twigs by length; creating geometric patterns	Improved number, measurement, pattern, and geometry concepts
Ecological Awareness	Environmental responsibility, biodiversity awareness, conservation	Responsible use of natural materials; sorting organic materials; exploring school environments	Increased environmental awareness and responsible behavior

Approaches to Learning	Curiosity, initiative, attention, persistence, exploration	Discovery-based play with natural materials and flexible activity choices	Increased engagement, intrinsic motivation, persistence, and exploratory behavior
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As shown in Table 2, the implications of APE-R extend beyond conventional academic outcomes and can be organized into five competency dimensions: (1) early academic competencies, including cognitive, language, numeracy, and science literacy; (2) personal competencies, including creativity, self-regulation, independence, and approaches to learning; (3) social competencies, including communication, collaboration, empathy, and conflict resolution; (4) psychomotor competencies, including fine-motor, gross-motor, and sensory development; and (5) ecological character, including environmental awareness and responsible interaction with nature. This multidimensional structure is consistent with evidence that nature-based and play-based learning can support multiple developmental domains simultaneously (Johnstone et al., 2022; Alotaibi, 2024). Thus, these five dimensions provide a conceptual foundation for positioning APE-R as a holistic pedagogical model.

The findings further indicate that the effectiveness of APE-R depends substantially on pedagogical implementation. Teachers need to select safe and developmentally appropriate materials, design challenging but achievable activities, observe children's responses, provide appropriate scaffolding, and connect play experiences with learning objectives. Teacher facilitation can extend children's exploration and interaction while maintaining children's autonomy (Smedsrud et al., 2024; Gordon et al., 2024; Khanna et al., 2026). Educational play tools also require appropriate pedagogical design to maximize their learning value (Dewi, 2023; Hifza et al., 2023). Overall, APE-R creates a learning ecosystem integrating authentic experience, active exploration, social interaction, creativity, developmental learning, and ecological awareness. Therefore, APE-R provides a conceptual foundation for contextual, exploratory, multisensory, collaborative, developmentally appropriate, and environmentally responsive early childhood learning (Prins et al., 2022; Yuhana & Nurlinda, 2026).

CONCLUSION

The most important finding of this study is that natural materials can be systematically transformed into Realistic Educational Play Tools (APE-R) when their authenticity, flexibility, multisensory engagement, contextuality, and sustainability are intentionally integrated with developmentally appropriate play activities. The synthesis demonstrates that APE-R has the potential to support holistic early childhood development across cognitive, language, motor,

social-emotional, creative, science, numeracy, and ecological domains, while emphasizing children's active exploration and meaningful interaction with their environment. The main scholarly contribution of this study lies in formulating a conceptual framework that connects natural-material affordances, realistic learning, open-ended play, teacher scaffolding, and developmental outcomes within an integrated pedagogical model. However, as a Systematic Literature Review, this study is limited by the availability, methodological diversity, and reported quality of existing publications and does not provide direct empirical validation of the proposed model. Future research should therefore develop, implement, and empirically test APE-R through classroom-based studies, experimental or design-based research, and longitudinal investigations across diverse early childhood contexts to examine its effectiveness, feasibility, safety, sustainability, and developmental impact.

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