The International Journal of Emerging Issues in Early Childhood Education (IJEIECE)

Vol. 8 No. 1 (2026)
p-ISSN 2655-9986; e-ISSN 2685-4074
https://doi.org/ 10.33830/ijeiece.v8i1.13594

Research Paper

Bridging Deep Learning and Nature-Based Learning for Early Childhood Creativity: A Systematic Literature Review

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Abstract

This systematic literature review examines the integration of deep learning technologies and nature-based learning (NBL) in fostering creativity in early childhood education. While both approaches have been widely studied independently, their combined potential remains underexplored, representing a significant gap in the literature. Guided by the PRISMA 2020 framework, this study identified 559 records published between 2014 and 2024 from major academic databases. After a rigorous screening and eligibility process, nine studies were included in the final thematic synthesis. The findings reveal a clear imbalance in the current research landscape. Nature-based learning consistently demonstrates strong contributions to creativity through exploratory play, multisensory engagement, and child-led inquiry, while deep learning technologies are primarily applied for assessment, personalization, and adaptive instruction, with limited focus on creativity development. Moreover, evidence of integration between these two domains remains scarce, with no established conceptual or empirical framework guiding their combined use. This review highlights three critical gaps: the absence of integrative pedagogical models, the concentration of studies in developed contexts, and the lack of validated creativity-specific assessment tools for young children. The study contributes by proposing an integrative perspective that positions deep learning as a supportive analytic tool within experiential, nature-based environments. Future research should focus on developing context-sensitive, ethically grounded, and pedagogically aligned models that enhance creativity without compromising children's agency, imagination, and interaction with the natural world.

Keywords: *early childhood creativity; nature-based learning; deep learning in education; experiential learning; adaptive learning*

To cite this article:
Riagandi. A, et al., (2026). Bridging Deep Learning and Nature-Based Learning for Early Childhood Creativity: A Systematic Literature Review. *The International Journal of Emerging Issues in Early Childhood Education (IJEIECE)*, 8(1), 1-19.
To link to this article: https://jurnal.ut.ac.id/index.php/ijeiece
Published by: Universitas Terbuka
Jl. Pd. Cabe Raya, Pd. Cabe Udik, Kec. Pamulang,
Kota Tangerang Selatan, Banten 15437

INTRODUCTION

Creativity has been increasingly recognized as a core competency in early childhood education, underpinning children's capacity for divergent thinking, problem-solving, and adaptive learning in complex and uncertain environments. Contemporary educational frameworks emphasize creativity not merely as artistic expression but as a fundamental cognitive process essential for lifelong learning and innovation. However, recent studies suggest that the development of creativity in early childhood remains inconsistent and highly sensitive to contextual factors, including learning environments, pedagogical approaches, and socio-emotional conditions (Leggett, 2024; Verger et al., 2024) . This issue is particularly critical given that early childhood represents a foundational period for cognitive development, during which creative thinking begins to interact with emerging executive functions such as cognitive flexibility, working memory, and self-regulation.

Despite its importance, opportunities for fostering creativity in early childhood settings are often constrained by increasingly structured and outcome-oriented educational practices. Such approaches may limit children's exploratory behaviors, imagination, and agency, which are essential components of creative development. Recent empirical evidence highlights that creativity in young children is shaped by complex interactions between cognitive, emotional, and environmental factors, rather than being a singular or isolated construct (Vaisarova, 2024) . In particular, the relationship between creativity and executive function remains nuanced and context-dependent, suggesting that creativity development requires learning environments that support flexibility, exploration, and meaningful engagement rather than rigid instruction.

In response to these challenges, nature-based learning (NBL) has emerged as a promising pedagogical approach that emphasizes direct interaction with natural environments. NBL facilitates multisensory engagement, experiential learning, and child-led inquiry, all of which are strongly associated with the development of creativity and holistic child development (Nurjanah et al., 2024) . By providing authentic and open-ended learning experiences, nature-based environments enable children to construct knowledge through exploration and imagination. However, while the benefits of NBL are well-documented, its implementation often lacks systematic assessment and scalability, particularly in formal education systems.

Concurrently, rapid advancements in artificial intelligence have introduced new possibilities for data-driven learning in education. In this study, *deep learning* refers specifically to a subset of artificial intelligence techniques that utilize neural networks to analyze complex patterns in large datasets for purposes such as learning analytics, adaptive instruction, and personalized feedback. Within early childhood education, these technologies have primarily been applied to monitoring learning progress and supporting individualized instruction. Although such applications demonstrate significant potential, current research indicates that the use of deep learning technologies remains largely focused on assessment and optimization, with limited attention to their role in fostering creativity or supporting exploratory learning processes.

A critical issue emerging from the literature is the fragmentation between experiential, nature-based pedagogies and data-driven technological approaches. Existing studies tend to examine nature-based learning and deep learning technologies independently, resulting in a lack of integrative frameworks that bridge ecological learning environments with intelligent systems. This gap is evident at three levels: (1) conceptually, there is limited theoretical integration between experiential learning and artificial intelligence in early childhood contexts; (2) methodologically, empirical studies rarely examine how these approaches interact in supporting creativity; and (3) contextually, most research is concentrated in specific regions, limiting its applicability across diverse socio-cultural settings.

Addressing this gap is essential, as the integration of nature-based learning and deep learning technologies may offer a more holistic approach to supporting creativity in early childhood. By combining rich, experiential environments with data-informed insights, educators may be better equipped to design responsive and adaptive learning experiences that preserve children's agency while enhancing pedagogical decision-making. Therefore, this study aims to systematically review literature published between 2014 and 2024 to examine how nature-based learning and deep learning have been conceptualized, implemented, and potentially integrated in fostering early childhood creativity.

This study contributes to the field in three ways. First, it synthesizes fragmented research on nature-based learning and deep learning within a unified analytical framework. Second, it identifies conceptual, methodological, and contextual gaps that limit current understanding of creativity development in early childhood. Third, it proposes an integrative perspective that informs future research and supports the development of pedagogically aligned and ethically grounded models of technology-enhanced learning. To guide this systematic review, four research questions are formulated: (1) How have research trends on early childhood creativity within nature-based learning evolved over the past decade (2014–2024)? (2) How has deep learning been applied in early childhood education, particularly to support creativity development? (3) What forms of integration exist between nature-based learning and deep learning technologies in enhancing early childhood creativity? (4) What are the research gaps related to the development of creativity in early childhood through nature-based and deep learning approaches?

LITERATURE REVIEW

Creativity in Early Childhood Education

Creativity in early childhood is increasingly conceptualized as a multidimensional construct encompassing cognitive, socio-emotional, and environmental dimensions. Recent systematic reviews highlight that creativity is closely linked to children's ability to engage in divergent thinking, exploratory play, and adaptive problem-solving, all of which are shaped by contextual learning experiences (Xu et al., 2025) . In early childhood settings, creativity is not solely an individual trait but emerges through dynamic interactions between the child and their environment, including pedagogical practices, social interactions, and material affordances.

Moreover, contemporary research emphasizes the strong relationship between creativity and executive functions, particularly cognitive flexibility and self-regulation. These cognitive processes enable children to generate novel ideas, shift perspectives, and sustain engagement in open-ended tasks. However, empirical findings indicate that creativity development is highly sensitive to environmental conditions, suggesting that structured and teacher-directed instruction may constrain children's creative potential. As a result, there is growing consensus that fostering creativity requires learning environments that prioritize autonomy, exploration, and experiential engagement.

Nature-Based Learning and Creativity Development

Nature-based learning (NBL) has emerged as a significant pedagogical approach that supports creativity through experiential, multisensory, and child-centered learning processes. A growing body of systematic reviews demonstrates that exposure to natural environments enhances children's cognitive, social, and emotional development, including creativity-related outcomes such as imagination, exploratory behavior, and flexible thinking (Johnstone et al., 2022). These findings suggest that natural environments provide rich and dynamic affordances that stimulate diverse forms of play, including imaginative, risky, and collaborative play.

In addition, nature-based learning has been shown to facilitate holistic development by integrating physical activity, emotional regulation, and environmental awareness. Outdoor learning environments encourage children to interact with complex and unpredictable stimuli, which in turn fosters creative problem-solving and adaptive thinking (Kiviranta et al., 2024) . Importantly, qualitative evidence indicates that creativity in nature-based settings often emerges through child-led inquiry and spontaneous exploration, rather than structured instructional activities.

Despite these benefits, the implementation of NBL faces several challenges. Systematic reviews highlight the lack of standardized definitions, inconsistent methodological approaches, and limited high-quality empirical evidence, particularly in early childhood contexts (Miller et al., 2021). Furthermore, research remains geographically concentrated, with limited representation from diverse socio-cultural settings, thereby restricting the generalizability of findings. These limitations indicate the need for more robust and context-sensitive research designs to better understand the mechanisms through which NBL supports creativity.

Deep Learning Technologies in Early Childhood Education

Advances in artificial intelligence have introduced new possibilities for enhancing learning processes through data-driven approaches. In the context of education, deep learning refers to machine learning models, particularly neural networks, that analyze large datasets to identify patterns, predict learning outcomes, and support adaptive instruction (Zawacki-Richter et al., 2019; Aravantinos et al., 2024). In early childhood education, these technologies have been increasingly applied in areas such as learning analytics, personalized feedback, and assessment systems, enabling more precise monitoring of children's developmental trajectories (Chen et al., 2022; Holmes & Tuomi, 2022).

Current literature suggests that deep learning technologies offer significant potential for improving the efficiency and responsiveness of educational practices. By capturing real-time data on children's learning behaviors, these systems enable educators to tailor instruction to individual needs and monitor developmental progress more effectively. However, existing research indicates that the application of deep learning in early childhood education remains largely instrumental, focusing on assessment and optimization rather than on fostering higher-order cognitive processes such as creativity (Aravantinos et al., 2024; Holmes et al., 2021).

A critical limitation in this area is the lack of pedagogical alignment between technological tools and developmentally appropriate practices. Early childhood learning is inherently play-based, exploratory, and relational, whereas many deep learning applications are designed for structured and measurable learning outcomes. This mismatch raises important questions about how artificial intelligence can be integrated into early childhood education without compromising children's agency, imagination, and social interaction (UNESCO, 2021; Holmes et al., 2022).

Toward an Integrative Framework: Bridging Nature-Based Learning and Deep Learning

Nature-based learning (NBL) has emerged as a significant pedagogical approach that supports creativity through experiential, multisensory, and child-centered learning processes. A growing body of systematic reviews demonstrates that exposure to natural environments enhances children's cognitive, social, and emotional development, including creativity-related outcomes such as imagination, exploratory behavior, and flexible thinking (Johnstone et al., 2022). These findings suggest that natural environments provide rich and dynamic affordances that stimulate diverse forms of play, including imaginative, risky, and collaborative play.

Recent empirical and review-based studies further emphasize that the design and quality of outdoor environments play a crucial role in shaping children's learning experiences. For instance, Craig et al. (2024) highlight that effective nature-based outdoor play and learning environments require intentional design elements, such as sensory-rich materials, opportunities for construction and manipulation, and integration of natural features, to support holistic development in early childhood. Importantly, their study reveals a significant lack of standardized guidelines and assessment frameworks for designing such environments, particularly for younger children, indicating a critical gap in the literature.

In addition, recent research underscores that the successful implementation of nature-based learning is influenced by systemic and contextual factors. Traynor et al. (2025) identify key enabling conditions including policy support, leadership, resource availability, and teacher capacity, that determine the extent to which outdoor learning becomes embedded in early childhood education practices. These findings suggest that while NBL has strong developmental benefits, its effectiveness depends on broader institutional and ecological systems that support sustained implementation. Furthermore, meta-level syntheses indicate that nature-based interventions consistently contribute to children's well-being, cognitive engagement, and creative expression, yet remain methodologically fragmented. Kaleta et al. (2025) argue that despite the growing number of studies, the field lacks integrative frameworks and consistent evaluation methods, particularly in linking environmental affordances with specific developmental outcomes such as creativity. This reinforces the need for more theoretically grounded and methodologically robust research to better understand how nature-based experiences translate into creative competencies.

RESEARCH METHOD

This study employed a Systematic Literature Review (SLR) approach to identify, evaluate, and synthesize previous studies relevant to the development of early childhood creativity through the integration of deep learning and nature-based learning approaches. The SLR method was selected because it enables researchers to obtain a comprehensive and evidence-based understanding of research trends, contributions, and gaps within a specific field (Page et al., 2021; Snyder, 2019).

Data Sources and Search Strategy

Data were collected from reputable international journals indexed in Scopus, Web of Science, SpringerLink, ScienceDirect, ERIC, and Google Scholar. The search was performed using specific keywords and Boolean operators to ensure comprehensive coverage of relevant studies. Table 1 presents the data sources and search strategy applied in this SLR.

Table 1. Data Sources and Literature Search Strategy

Aspect	Description
Type of Data Source	Peer-reviewed international journals
Databases Used	Scopus, Web of Science, SpringerLink, ScienceDirect, ERIC, Google Scholar
Search Keywords	"early childhood creativity"; "deep learning in early childhood education"; "nature-based learning" OR "outdoor learning"; "AI and creativity in young children"; "environment-based education AND creativity"
Boolean Combination	("deep learning" AND "creativity" AND "early childhood")
Publication Year Range	2014 – 2024
Language	English
Access Type	Full-text articles

Inclusion and Exclusion Criteria

To ensure the relevance and quality of the selected studies, a systematic inclusion–exclusion process was applied. Only articles that met specific criteria, such as clear methodology, full-text availability, and relevance to early childhood creativity, were included. Table 2 summarizes the inclusion and exclusion criteria.

Table 2. Inclusion and Exclusion Criteria

Aspect	Inclusion Criteria	Exclusion Criteria
Publication Type	Peer-reviewed empirical or review journal articles	Non-scholarly works (blogs, policy reports, unindexed proceedings)
Publication Year	2014–2024	Before 2014
Language	English	Non-English
Research Subject	Children aged 3–8 years in educational contexts	Elementary, secondary, or higher education subjects
Main Topic	Early childhood creativity, nature-based learning, or deep learning in education	Studies unrelated to these three topics
Article Access	Full-text accessible	Abstract only or restricted access
Methodology	Clear and replicable research method	Method not explicitly described
Study Quality	Theoretical or empirical contribution to creativity development	No significant contribution to creativity development

Screening and Analysis Process

The article selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, encompassing four main stages: (1) Identification, (2) Screening, (3) Eligibility checking, and (4) Inclusion. Only studies meeting all inclusion criteria proceeded to the data extraction and thematic synthesis stages. Each selected article was coded according to eight analytical categories: (1) Title and author(s); (2) Year and publication source; (3) Research objectives; (4) Method and sample; (5) Thematic focus (deep learning/nature-based/creativity); (6) Main findings; (7) Educational implications; and (8) Identified research gaps. The extracted data were then analyzed using thematic analysis to identify recurring patterns, conceptual trends, and research gaps across studies (Nowell et al., 2017; Braun & Clarke, 2019). This process included open coding, data categorization, and narrative synthesis to construct a conceptual understanding of how deep learning and nature-based approaches have been discussed in early childhood creativity literature.

Analytical Approach

Data analysis was conducted iteratively and inductively, involving repeated reading of the articles, highlighting relevant sections, and grouping findings into major themes such as, the influence of nature-based learning on creativity, the use of artificial intelligence in early childhood education, and integrative models combining technology and contextual learning. Comparative analysis among studies allowed the identification of methodological variations, consistencies, and underexplored areas. The final stage involved synthesizing these themes to propose a conceptual integrative framework bridging nature-based pedagogy and intelligent technologies in supporting early childhood creativity. This method was chosen for its effectiveness in synthesizing interdisciplinary literature, especially on topics combining technology and naturalistic pedagogy. Thematic synthesis has also been recommended for handling heterogeneous studies in design and context (Siddaway, Wood, & Hedges, 2019).

Quality Appraisal

A structured quality appraisal was planned to support interpretation of evidence strength. For empirical studies, appraisal criteria can be applied using an established mixed-methods tool (for example, the Mixed Methods Appraisal Tool) to examine sampling adequacy, measurement quality, risk of bias, and clarity of analysis. Quality ratings should be reported and used to contextualize conclusions, rather than to exclude studies by default. For review-type articles, appraisal criteria should focus on transparency of search, selection, and synthesis procedures. The final manuscript should report the appraisal procedure, the number of reviewers involved, and a summary of quality judgments.

RESULTS AND DISCUSSION

Results

This section presents the findings of the Systematic Literature Review (SLR) and discusses their implications in relation to the integration of deep learning and nature-based learning in promoting creativity among early childhood learners. The results are organized according to the four research questions (RQ1–RQ4), supported by critical comparison with previous studies. To ensure transparency and traceability of the literature selection process, the PRISMA 2020 framework was applied. A total of 559 records were identified across sources. After removing 90 duplicates, 469 records were screened by title and abstract. A total of 370 records were excluded as off-topic, leaving 99 reports for full-text eligibility assessment. Of these, 90 reports were excluded for reasons such as non-ECE populations, lack of relevance to creativity, non-empirical commentary, or insufficient methodological detail. Finally, nine studies met all inclusion criteria and were included in the thematic synthesis.

Figure 1 illustrates the systematic literature selection process guided by the PRISMA 2020 framework. The figure details each stage of the review, including identification, screening, eligibility, and inclusion, providing a transparent account of how the initial pool of studies was progressively refined. Through a rigorous filtering process involving duplicate removal, relevance screening, and application of inclusion and exclusion criteria, a final set of studies was selected for analysis. This procedure enhances the credibility and replicability of the review by ensuring that only methodologically sound and contextually relevant studies were included.

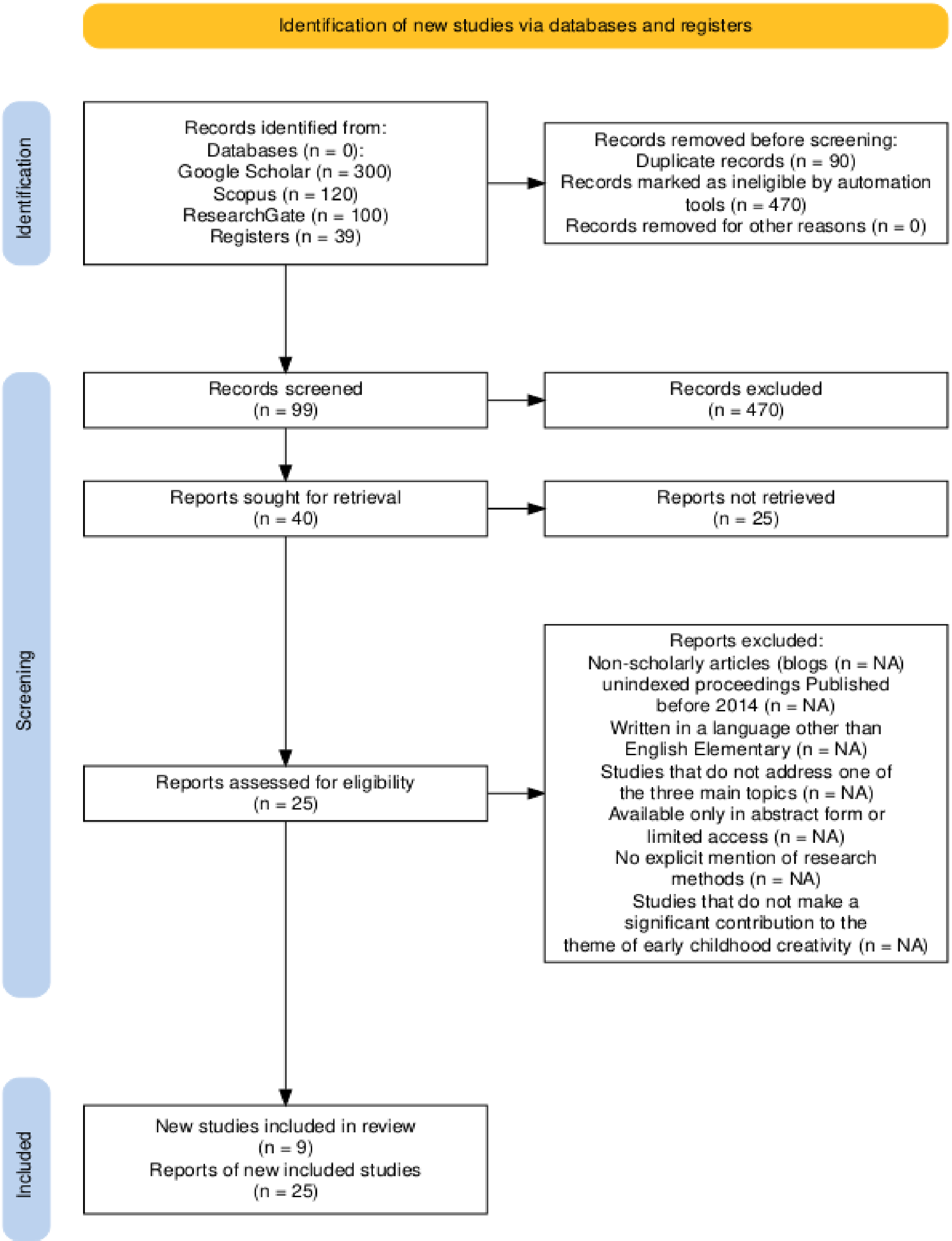

Figure 1. PRISMA Flow Diagram of Article Selection

Figure 1 illustrates the systematic study selection process following the PRISMA 2020 framework. The initial search across multiple sources yielded a total of 559 records, comprising 300 from Google Scholar, 120 from Scopus, 100 from ResearchGate, and 39 from other registers. Prior to screening, a substantial number of records (n = 560) were removed due to duplication (n = 90) and automatic filtering as ineligible (n = 470), resulting in 99 records that proceeded to the screening stage.

During the screening phase, titles and abstracts were evaluated based on relevance to the research focus, leading to the exclusion of 470 records. Subsequently, 40 full-text articles were sought for retrieval; however, 25 reports could not be accessed, leaving 25 studies for eligibility assessment. At the eligibility stage, studies were further evaluated using predefined inclusion and exclusion criteria, including publication type, language, methodological clarity, and relevance to early childhood creativity, nature-based learning, and deep learning.

Following this rigorous selection process, a final set of nine studies was included in the qualitative synthesis. The relatively small number of included studies indicates that, despite a broad initial pool of literature, only a limited body of research directly addresses the intersection of nature-based learning, deep learning technologies, and early childhood creativity. This finding highlights a significant gap in the literature and underscores the need for more integrative and empirically grounded research in this emerging field.

Table 3 presents the characteristics and key findings of the nine core studies included in this systematic literature review. The table provides a structured overview of each study's context, methodological approach, research focus aligned with the four research questions (RQ1–RQ4), and principal findings related to early childhood creativity, nature-based learning (NBL), and deep learning technologies. By synthesizing evidence across diverse geographical contexts and research designs, this table serves as a foundation for identifying dominant trends, methodological patterns, and critical gaps in the current body of knowledge. Furthermore, it enables a comparative understanding of how different approaches, experiential and technology-driven, have been explored and to what extent they contribute to the development of creativity in early childhood education.

Table 3. Characteristics of Included Studies (n = 9)

No	Author(s)	Year	Country	Method	Focus (RQ)	Key Findings
1	Johnstone et al.	2022	Multi-country	Mixed-method SLR	RQ1	NBL enhances creativity via exploration, play, and multisensory engagement
2	Kiviranta et al.	2024	Finland	Systematic review	RQ1	Outdoor learning improves creativity and self-regulation
3	Miller et al.	2021	Global	Quantitative SLR	RQ1	Strong evidence of NBL impact on cognitive & creative outcomes
4	Craig et al.	2024	Global	Review	RQ1	Design of natural environments influences creativity
5	Traynor et al.	2025	UK	Quasi-experimental	RQ1/RQ4	Implementation depends on institutional & policy support
6	Aravantinos et al.	2024	Global	Systematic review	RQ2	AI used for assessment, not creativity
7	Chen et al.	2022	Global	Review	RQ2	AI supports adaptive learning but lacks creative focus
8	Holmes & Tuomi	2022	Europe	Review	RQ2/RQ4	AI lacks pedagogical alignment in early childhood
9	Kaleta et al.	2025	Global	Review of reviews	RQ3/RQ4	No integrative framework linking NBL and AI

The data presented in Table 3 reveal several important patterns across the nine core studies. First, there is a clear dominance of research focusing on nature-based learning (RQ1), with five out of nine studies emphasizing its role in enhancing creativity. These studies consistently demonstrate that natural environments support creativity through exploratory play, multisensory engagement, and child-led inquiry. Moreover, evidence from both systematic reviews and empirical studies suggests that nature-based learning not only fosters creative thinking but also contributes to broader developmental domains such as self-regulation and socio-emotional competence. This indicates a strong and well-established evidence base for the role of ecological and experiential learning environments in early childhood creativity.

Second, studies addressing deep learning and artificial intelligence in early childhood education (RQ2) are fewer and reveal a markedly different pattern. The findings consistently show that AI technologies are primarily used for assessment, adaptive instruction, and monitoring learning progress, rather than for directly fostering creativity. This suggests that current applications of deep learning remain largely instrumental and efficiency-oriented. Importantly, the absence of creativity-focused AI applications highlights a conceptual limitation in how technology is positioned within early childhood education, favoring measurable outcomes over open-ended, exploratory processes.

Third, the integration of nature-based learning and deep learning (RQ3) appears to be highly limited. Only one study (Kaleta et al., 2025) explicitly addresses this intersection, and even then, it emphasizes the absence of an integrative framework. This finding confirms that the potential synergy between ecological learning environments and intelligent systems remains largely underexplored. As a result, current research does not yet provide sufficient empirical or theoretical grounding for understanding how these two domains can be effectively combined to support creativity.

Finally, several cross-cutting gaps (RQ4) emerge from the synthesis. These include the lack of pedagogical alignment between AI technologies and developmentally appropriate practices, the strong concentration of studies in developed contexts, and the absence of validated, creativity-specific assessment tools. Additionally, the methodological distribution shows a dominance of review-based studies, with relatively limited experimental or longitudinal research, indicating a need for more robust empirical evidence.

Overall, the data suggest a fragmented research landscape characterized by a strong foundation in nature-based learning, a rapidly developing but narrowly applied use of artificial intelligence, and a critical lack of integrative approaches. This imbalance underscores the need for interdisciplinary frameworks that bridge experiential and data-driven learning paradigms, while maintaining a focus on creativity as a central outcome in early childhood education.

Table 4 synthesizes the main findings of the reviewed studies in relation to the four research questions, providing a comparative overview of trends, applications, and research gaps in the literature. The table reveals a clear imbalance in the current body of knowledge, with substantial attention given to nature-based learning and its impact on creativity, while the application of deep learning technologies remains largely limited to assessment and optimization purposes. Moreover, the integration of these two domains appears to be in its early stages, with only a small number of studies exploring their potential synergy. This synthesis not only highlights the fragmented nature of existing research but also underscores the need for more integrative, context-sensitive, and creativity-focused approaches in early childhood education.

Table 4. Synthesized Findings Across Research Questions

Research Question	Synthesized Findings
RQ1: Trends in Nature-Based Learning and Creativity	The majority of reviewed studies (5 out of 9) consistently demonstrate that nature-based learning enhances early childhood creativity through exploratory play, multisensory engagement, and child-led inquiry. These approaches are also linked to broader developmental outcomes, including self-regulation and socio-emotional competence, indicating a strong and well-established evidence base.
RQ2: Application of Deep Learning in Early Childhood Education	A smaller subset of studies (3 out of 9) shows that deep learning technologies are primarily applied in assessment, adaptive learning, and personalized feedback systems. However, their direct contribution to creativity development remains limited, with most applications focusing on efficiency and measurable learning outcomes rather than open-ended creative processes.
RQ3: Integration of Deep Learning and Nature-Based Learning	Only one study explicitly addresses the integration of deep learning and nature-based learning, highlighting the absence of a coherent conceptual or empirical framework. Existing evidence suggests potential synergy through smart learning environments, but this area remains underexplored and fragmented.
RQ4: Research Gaps	The synthesis identifies three major gaps: (1) lack of integrative frameworks combining ecological and technological approaches, (2) dominance of studies conducted in developed contexts, limiting generalizability, and (3) absence of validated, creativity-specific assessment tools in early childhood education.

Discussion

This section critically interprets the findings of the systematic literature review by examining how current research addresses the intersection of nature-based learning, deep learning technologies, and early childhood creativity. Moving beyond descriptive reporting, the discussion synthesizes evidence across studies to identify dominant trends, conceptual tensions, and unresolved challenges within the field. The findings reveal a persistent imbalance between experiential and technology-driven approaches, with nature-based learning strongly associated with creativity development, while deep learning technologies remain largely confined to assessment and optimization functions. This divergence highlights a fundamental gap in the literature, where the potential synergy between ecological learning environments and intelligent systems remains underdeveloped. By situating these findings within broader pedagogical and technological discourses, this section argues for the need to move toward integrative, context-sensitive, and creativity-oriented models of early childhood education.

RQ1: Trends in Nature-Based Learning and Early Childhood Creativity

The findings indicate that nature-based learning has become one of the most consistently discussed approaches in the literature on early childhood creativity. Across recent studies, nature-based learning is increasingly conceptualized not merely as outdoor activity, but as a holistic pedagogical environment that offers open-ended, sensory-rich, and socially interactive experiences. This is significant because creativity in early childhood is strongly shaped by opportunities for exploration, imagination, risk-taking, and flexible thinking. Contemporary evidence shows that participation in nature-based programs is associated with gains in children's creativity, engagement, and overall developmental outcomes, reinforcing the idea that natural environments provide meaningful affordances for learning beyond formal instruction (Dankiw et al., 2020). A key shift in the literature is the reconceptualization of nature from a passive "setting" into an active pedagogical resource that supports inquiry, experimentation, and meaning-making through play.

Natural elements such as outdoor spaces, weather variation, vegetation, water, and loose parts create dynamic and unpredictable learning conditions that are highly conducive to creative thinking. These environments encourage children to generate multiple ideas, test hypotheses, and construct knowledge through direct interaction with their surroundings. Research suggests that such experiential learning contexts are closely linked to improvements in executive functioning and creative problem-solving, particularly when children are given autonomy and time for exploration (Chawla, 2020). Moreover, creativity appears to be fostered indirectly through the development of self-regulation, socio-emotional competence, and cognitive flexibility. Children engaged in nature-based activities often encounter collaborative and uncertain situations that require negotiation, emotional control, and adaptive thinking, which are foundational processes for creativity development.

Despite these strengths, the literature also highlights several limitations and areas for further investigation. Recent studies emphasize that simply providing outdoor exposure is insufficient; rather, creativity is more effectively supported through intentionally designed nature-based environments that incorporate sensory diversity, opportunities for experimentation, and flexible, child-led learning structures (Mygind et al., 2021). In addition, many studies continue to treat creativity as a secondary or inferred outcome, relying on proxies such as engagement or problem-solving instead of validated creativity-specific measures. There is also a notable concentration of research in regions with established outdoor learning traditions, which limits generalizability across diverse cultural and educational contexts. Overall, while nature-based learning represents a strong and well-supported foundation for fostering creativity in early childhood, future research should prioritize more rigorous assessment methods, clearer pedagogical frameworks, and broader contextual representation to deepen understanding of its impact.

RQ2: Application of Deep Learning in Early Childhood Education

The findings indicate that the application of deep learning and broader AI-based technologies in early childhood education remains emerging, fragmented, and relatively narrow in purpose. Current studies suggest that AI in early childhood contexts is more frequently introduced through AI literacy, robotics, machine learning exploration, and adaptive digital tools rather than through direct creativity-oriented deep learning systems. Su and Yang (2022) show that AI applications in early childhood education are still at an early stage, with most studies focusing on children's understanding of AI concepts, computational thinking, robotics, and digital interaction rather than creativity as a primary developmental outcome. Similarly, Yang (2022) argues that AI education for young children requires age-appropriate, embodied, and culturally responsive curriculum design, indicating that the pedagogical framing of AI remains more developed than its use as a creativity-enhancement mechanism.

A deeper analysis suggests that AI-based learning in early childhood is still largely instrumental. It is commonly used to support assessment, personalization, engagement, and inquiry-based interaction, but not yet to cultivate open-ended creativity in a systematic way. For example, Vartiainen et al. (2020) demonstrate that very young children can meaningfully explore machine learning through tools such as Teachable Machine, but the focus is mainly on understanding how machine learning works rather than using it to expand creative expression. Kewalramani et al. (2021) further show that AI-interfaced robotic toys can support children's inquiry literacy, including creative, emotional, and collaborative inquiry; however, such applications depend heavily on teacher mediation, play-based pedagogy, and dialogic interaction.

This suggests that AI does not automatically foster creativity; its impact depends on whether the technology is embedded in exploratory, relational, and child-centered learning experiences.

The main limitation, therefore, is not the absence of AI potential, but the lack of pedagogical alignment between AI systems and early childhood creativity development. Many AI applications are designed around measurable outputs, prediction, classification, and adaptive feedback, whereas creativity in early childhood requires imagination, ambiguity, experimentation, and children's agency. Su et al. (2023) identify persistent challenges in early AI literacy, including limited teacher readiness, lack of curriculum models, and insufficient teaching guidelines, while Samuelsson (2023) emphasizes the need to include children's voices, play, and imaginaries when introducing robots and AI in preschool contexts. Taken together, these studies indicate that future research should move beyond using AI merely for monitoring or efficiency and should instead design AI-supported environments that intentionally promote creativity, playfulness, ethical engagement, and meaningful child–technology interaction.

RQ3: Integration of Deep Learning and Nature-Based Learning

The findings indicate that the integration between nature-based learning and deep learning technologies remains at an early and underdeveloped stage. Existing evidence does not yet show a mature pedagogical model that explicitly combines outdoor, ecological, and experiential learning with deep learning systems to foster early childhood creativity. However, recent studies on smart learning environments suggest a possible direction for this integration. Smart learning environments increasingly use sensors, learning analytics, IoT, and AI to capture contextual data and provide adaptive feedback, but these systems often remain focused on efficiency, monitoring, and personalization rather than creativity-oriented pedagogy (Maulidiya et al., 2024; Fütterer et al., 2025). This suggests that the main gap is not only technological, but conceptual: current systems are able to collect and analyze learning data, yet they rarely translate such data into pedagogical strategies that support imagination, exploration, and child-led inquiry.

A promising pathway can be seen in emerging work on AIoT and environmentally responsive learning systems. Tabuenca et al. (2024), for example, demonstrate how Artificial Intelligence of Things (AIoT) can be used in smart learning environments to monitor plants, environmental conditions, and patterns of human presence, creating opportunities for more adaptive and ecologically informed learning experiences. Similarly, Tabuenca et al. (2023) show that IoT-based environmental awareness systems can connect plant-based learning activities with real-time data, supporting learners' understanding of ecological processes. Although these studies are not specifically designed for early childhood creativity, they provide an important conceptual bridge: technology can be used not to replace direct experience with nature, but to make environmental interactions more visible, interpretable, and pedagogically actionable. In early childhood contexts, such systems could help teachers document children's engagement with natural materials, observe patterns of inquiry, and design responsive activities that preserve playfulness and agency.

Nevertheless, the integration of deep learning and nature-based learning must be approached cautiously. Evidence from AI-based classroom management shows that machine learning and deep learning are often used for attention tracking, behavior monitoring, and engagement assessment, while ethical issues such as privacy, data security, and algorithmic bias remain underreported (Fütterer et al., 2025). This is particularly important in early childhood education, where children's autonomy, emotional safety, and embodied interaction with the environment must remain central. García-Domínguez et al. (2020) show that deep neural networks can classify children's activities using environmental sound data, illustrating the technical possibility of non-wearable monitoring in child-related contexts; however, such approaches should not reduce children's creative experiences to measurable behavioral signals. Therefore, future research should develop an integrative framework that positions deep learning as a supportive analytic layer for teachers, while nature-based learning remains the core experiential and relational foundation for creativity development.

RQ4: Synthesis of Research Gaps Across RQ1–RQ3

Across the three research questions, the first critical gap concerns the absence of an integrative framework that explicitly connects deep learning technologies, nature-based learning, and creativity development in early childhood education. Existing studies tend to treat these domains separately: nature-based learning is often discussed through ecological, experiential, and play-based perspectives, while deep learning technologies are usually framed through learning analytics, prediction, assessment, or adaptive instruction. This separation limits the field's ability to explain how data-driven systems could support, rather than disrupt, children's embodied exploration, imagination, and agency in natural environments. Recent work on digital technologies and early childhood nature connection shows that technology can support child–nature interaction, but the field still needs stronger theoretical grounding, clearer attention to children's agency, and more explicit design principles for integrating digital tools with nature-based experiences (Vella et al., 2023). Similarly, emerging studies on AI affordances in early childhood education highlight that global research remains uneven and fragmented, particularly in translating AI capabilities into pedagogically meaningful practices for young children (Chen, 2024).

The second gap relates to contextual imbalance and limited generalizability. Much of the evidence on both nature-based learning and AI-supported early childhood education is still shaped by research traditions, infrastructure, and policy environments in developed contexts. This is problematic because assumptions about outdoor learning, child agency, creativity, and digital access are not culturally neutral. In diverse educational settings, including postcolonial and Global South contexts, early childhood education is deeply shaped by local knowledge, community values, indigenous practices, material resources, and uneven access to technology. Tesar and Pangastuti's discussion of Indonesian early childhood education emphasizes that global educational paradigms often overshadow local contexts and may marginalize culturally situated understandings of childhood, learning, and development (Tesar & Pangastuti, 2024). This suggests that future research should not simply transfer models of nature-based learning or AI-enabled education from high-resource contexts, but should examine how such models can be reinterpreted through culturally responsive, locally grounded, and equity-oriented frameworks.

The third gap concerns the shortage of validated, creativity-specific assessment tools that are developmentally appropriate for young children, especially in studies combining ecological and technology-enhanced learning environments. Many studies infer creativity from related indicators such as engagement, curiosity, problem-solving, or divergent behavior, but do not directly assess creativity using robust and age-sensitive instruments. This weakens the precision of claims about whether nature-based or AI-supported learning actually enhances creativity. Long et al. (2022) show that creativity assessment in education remains dominated by divergent thinking tests, self-report measures, and product-based judgments, each of which has limitations when applied to young children. In AI-supported contexts, the problem becomes more complex because children's data may be collected through automated systems, raising ethical concerns around privacy, algorithmic bias, transparency, and developmental appropriateness. Berson et al. (2025) emphasize that AI use in early childhood education requires governance frameworks that protect children's rights, privacy, and developmental needs. Therefore, future studies should develop assessment models that are not only psychometrically valid, but also ethical, child-centered, culturally responsive, and capable of capturing creativity as a process rather than merely as a measurable product.

CONCLUSIONS

This study provides a comprehensive synthesis of research on the intersection of nature-based learning, deep learning technologies, and early childhood creativity. The findings indicate that nature-based learning represents a well-established and effective pedagogical approach for fostering creativity, primarily through its emphasis on exploration, sensory engagement, and child-centered inquiry. In contrast, deep learning technologies remain largely instrumental, focusing on assessment, personalization, and efficiency rather than directly supporting creative processes. A key contribution of this review is the identification of a fundamental imbalance between experiential and technology-driven approaches. While both domains offer significant potential, their integration remains limited and conceptually underdeveloped. This fragmentation highlights the need for interdisciplinary frameworks that bridge ecological learning environments with intelligent systems in a way that supports creativity as a central educational outcome. Importantly, the findings suggest that deep learning should not replace experiential learning, but rather function as a complementary tool that enhances pedagogical decision-making while preserving children's agency and engagement. Overall, this study advances the field by articulating a more holistic and integrative perspective on early childhood education. It underscores the importance of aligning technological innovation with developmentally appropriate, play-based, and context-sensitive pedagogies to ensure that creativity remains at the core of learning in early childhood.

LIMITATION & FURTHER RESEARCH

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the review included a relatively small number of studies (n = 9), reflecting the limited availability of research that explicitly addresses the intersection of nature-based learning, deep learning technologies, and early childhood creativity. This constraint limits the generalizability of the findings and indicates that the field is still emerging. Second, the included studies show considerable methodological heterogeneity, including systematic reviews, empirical studies, and conceptual analyses. While this diversity enriches the synthesis, it also makes direct comparison and generalization more challenging. In addition, many studies focus on broader developmental outcomes rather than explicitly measuring creativity, which may affect the precision of conclusions regarding creativity development. Third, the literature reviewed is predominantly drawn from developed contexts, where access to natural environments and technological infrastructure is relatively well established. As a result, the findings may not fully represent diverse socio-cultural and educational settings, particularly in low-resource contexts.

Further Research

Future research should focus on developing integrative and interdisciplinary frameworks that explicitly connect nature-based learning and deep learning technologies in supporting early childhood creativity. There is a need for empirical studies, particularly experimental and longitudinal designs, that examine how these approaches interact in real educational settings. In addition, future studies should prioritize the development and validation of creativity-specific assessment tools that are developmentally appropriate for young children. Such tools should capture creativity as a dynamic and process-oriented construct, rather than relying solely on indirect indicators such as engagement or problem-solving. Finally, research should expand to include diverse socio-cultural contexts to enhance the generalizability and relevance of findings. This includes exploring how local knowledge, cultural practices, and contextual constraints shape the implementation of both nature-based and technology-enhanced learning. Ethical considerations, including data privacy, children's agency, and the responsible use of artificial intelligence, should also be central to future research agendas.

REFERENCES

Aravantinos, S., Lavidas, K., Voulgari, I., Papadakis, S., Karalis, T., & Komis, V. (2024). Educational approaches with artificial intelligence in primary school settings: A systematic review. *Education Sciences, 14*(7), 744. https://doi.org/10.3390/educsci14070744

Berson, I. R., Berson, M. J., & Luo, W. (2025). Innovating responsibly: Ethical considerations for AI in early childhood education. *AI, Brain and Child, 1*, Article 2. https://doi.org/10.1007/s44436-025-00003-5

Branquinho, C., et al. (2026). Unlocking youth creativity: The role of socioemotional skills and well-being. *Frontiers in Psychology, 17*, 12939378. https://doi.org/10.3390/children13020261

Chawla, L. (2020). Childhood nature connection and constructive hope: A review of research on connecting with nature and coping with environmental loss. *People and Nature, 2*(3), 619–642. https://doi.org/10.1002/pan3.10128

Chen, J. J. (2024). A scoping study on AI affordances in early childhood education: Mapping the global landscape, identifying research gaps, and charting future research directions. *Journal of Artificial Intelligence Research, 81*, 701–740. https://doi.org/10.1613/jair.1.16882

Chen, L., Chen, P., & Lin, Z. (2022). Artificial intelligence in education: A review. *IEEE Access, 10*, 75264–75278. 10.1109/ACCESS.2020.2988510

Chen, X., Xie, H., Zou, D., & Hwang, G.-J. (2020). Application and theory gaps during the rise of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 1*, 100002. https://doi.org/10.1016/j.caeai.2020.100002

Chiu, T. K. F., Xia, Q., Zhou, X., Chai, C. S., & Cheng, M. (2023). Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 4*, 100118. https://doi.org/10.1016/j.caeai.2022.100118

Craig, D., et al. (2024). Effective nature-based outdoor play and learning environments for young children. *Early Childhood Education Journal*. https://doi.org/10.3390/ijerph21091247

Craig, D., Trina, N. A., Monsur, M., Haque, U. T., Farrow, G., Hasan, M. Z., Tasnim, F., & Akinbobola, M. S. (2024). Effective nature-based outdoor play and learning environments for below-3 children: A literature-based summary. *International Journal of Environmental Research and Public Health, 21*(9), 1247. https://doi.org/10.3390/ijerph21091247

Dankiw, K. A., Tsiros, M. D., Baldock, K. L., & Kumar, S. (2020). The impacts of unstructured nature play on health in early childhood development: A systematic review. *PLOS ONE, 15*(2), e0229006. https://doi.org/10.1371/journal.pone.0229006

Fütterer, T., Goldberg, P., Bühler, B., Sikimić, V., Trautwein, U., Gerjets, P., Stürmer, K., & Kasneci, E. (2025). Artificial intelligence in classroom management: A systematic review on educational purposes, technical implementations, and ethical considerations. *Computers and Education: Artificial Intelligence, 9*, 100483. https://doi.org/10.1016/j.caeai.2025.100483

García-Domínguez, A., Galvan-Tejada, C. E., Zanella-Calzada, L. A., Gamboa, H., Galván-Tejada, J. I., Celaya Padilla, J. M., Luna-García, H., Arceo-Olague, J. G., & Magallanes-Quintanar, R. (2020). Deep artificial neural network based on environmental sound data for the generation of a children activity classification model. *PeerJ Computer Science, 6*, e308. https://doi.org/10.7717/peerj-cs.308

Holmes, W., & Tuomi, I. (2022). State of the art and practice in AI in education. *European Journal of Education, 57*(4), 542–570. https://doi.org/10.1111/ejed.12533

Holmes, W., Bialik, M., & Fadel, C. (2021). Artificial intelligence in education: Promises and implications for teaching and learning. *Computers and Education: Artificial Intelligence, 2*, 100016. https://doi.org/10.1016/j.caeai.2021.100016

Hwang, G.-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 1*, 100001. https://doi.org/10.1016/j.caeai.2020.100001

Johnstone, A., Martin, A., Cordovil, R., Fjørtoft, I., Iivonen, S., Jidovtseff, B., Lopes, F., Reilly, J. J., Thomson, H., Wells, V., & McCrorie, P. (2022). Nature-based early childhood education and children's social, emotional and cognitive development: A mixed-methods systematic review. *International Journal of Environmental Research and Public Health, 19*(10), 5967. https://doi.org/10.3390/ijerph19105967

Kaleta, B., Campbell, S., & Burke, J. (2025). Nature-based interventions: A systematic review of reviews. *Frontiers in Psychology, 16*, 1625294. https://doi.org/10.3389/fpsyg.2025.1625294

Kewalramani, S., Kidman, G., & Palaiologou, I. (2021). Using artificial intelligence (AI)-interfaced robotic toys in early childhood settings: A case for children's inquiry literacy. *European Early Childhood Education Research Journal, 29*(5), 652–668. https://doi.org/10.1080/1350293X.2021.1968458

Kiviranta, L., Lindfors, E., Rönkkö, M.-L., & Luukka, E. (2024). Outdoor learning in early childhood education: Exploring benefits and challenges. *Educational Research, 66*(1), 102–119. https://doi.org/10.1080/00131881.2023.2285762

Kucirkova, N., & Littleton, K. (2023). Digital technologies and creativity in early childhood education: A systematic review. *British Journal of Educational Technology, 54*(1), 4–22. https://doi.org/10.1111/bjet.13252

Leggett, N. (2024). Creativity in early childhood: How educators from Australia and Italy are documenting the creative thought processes of young children. *SN Social Sciences, 4*, 74. https://doi.org/10.1007/s43545-024-00873-1

Long, H., Kerr, B. A., Emler, T. E., & Birdnow, M. (2022). A critical review of assessments of creativity in education. *Review of Research in Education, 46*(1), 288–323. https://doi.org/10.3102/0091732X221084326

Maulidiya, D., Nugroho, B., Santoso, H. B., & Hasibuan, Z. A. (2024). Thematic evolution of smart learning environments, insights and directions from a 20-year research milestones: A bibliometric analysis. *Heliyon, 10*(5), e26191. https://doi.org/10.1016/j.heliyon.2024.e26191

Miller, N. C., Kumar, S., Pearce, K. L., & Baldock, K. L. (2021). The outcomes of nature-based learning for primary school aged children: A systematic review of quantitative research. *Environmental Education Research, 27*(8), 1115–1140. https://doi.org/10.1080/13504622.2021.1921117

Mygind, E., Stevenson, M. P., Liebst, L. S., Konvalinka, I., & Bentsen, P. (2021). Stress response and cognitive performance modulation in classroom versus natural environments: A quasi-experimental pilot study with children. *International Journal of Environmental Research and Public Health, 18*(15), 7937. 10.3390/ijerph15061098

Nurjanah, N. E., Yetti, E., & Sumantri, M. S. (2024). Developing creative thinking in preschool children: A comprehensive review of innovative approaches. *European Journal of Educational Research, 13*(3), 1303–1319. https://doi.org/10.12973/eu-jer.13.3.1303

Ouyang, F., & Jiao, P. (2021). Artificial intelligence in education: The three paradigms. *Computers and Education: Artificial Intelligence, 2*, 100020. https://doi.org/10.1016/j.caeai.2021.100020

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

Prins, J., Ball, J., & Sutherland, R. (2022). Nature play in early childhood education: A systematic review. *International Journal of Environmental Research and Public Health, 19*(22), 15093. https://doi.org/10.3390/ijerph192215093

Rymanowicz, K., Hetherington, C., & Larm, B. (2020). Planting the seeds for nature-based learning: Impacts of a farm- and nature-based early childhood education program. *International Journal of Early Childhood Environmental Education, 8*(1), 44–63. https://doi.org/10.13140/RG.2.2.20354.15045

Samuelsson, R. (2023). A shape of play to come: Exploring children's play and imaginaries with robots and AI. *Computers and Education: Artificial Intelligence, 5*, 100173. https://doi.org/10.1016/j.caeai.2023.100173

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Su, J., & Yang, W. (2022). Artificial intelligence in early childhood education: A scoping review. *Computers and Education: Artificial Intelligence, 3*, 100049. https://doi.org/10.1016/j.caeai.2022.100049

Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). Artificial intelligence (AI) literacy in early childhood education: The challenges and opportunities. *Computers and Education: Artificial Intelligence, 4*, 100124. https://doi.org/10.1016/j.caeai.2023.100124

Tabuenca, B., Moreno-Sancho, J.-L., Arquero-Gallego, J., Greller, W., & Hernández-Leo, D. (2023). Generating an environmental awareness system for learning using IoT technology. *Internet of Things, 22*, 100756. https://doi.org/10.1016/j.iot.2023.100756

Tabuenca, B., Uche-Soria, M., Greller, W., Hernández-Leo, D., Balcells-Falgueras, P., Gloor, P., & Garbajosa, J. (2024). Greening smart learning environments with Artificial Intelligence of Things. *Internet of Things, 25*, 101051. https://doi.org/10.1016/j.iot.2023.101051

Tesar, M., & Pangastuti, Y. (2024). From colonial legacies to inclusive futures: Transforming and reconceptualising early childhood education in Indonesia. *Global Studies of Childhood, 14*(3), 301–314. https://doi.org/10.1177/20436106241268149

Traynor, O., et al. (2025). Evaluating outdoor nature-based play and learning provision in early childhood education. *Pilot and Feasibility Studies*. https://doi.org/10.1186/s40814-025-01721-6

Traynor, O., Martin, A., Chng, N. R., & McCrorie, P. (2025). The feasibility of evaluating outdoor nature-based early childhood education and care provision: A pilot quasi-experimental design. *Pilot and Feasibility Studies, 11*, 137. https://doi.org/10.1186/s40814-025-01721-6

Trina, N. A., Craig, D., & Farrow, G. (2024). How do nature-based outdoor learning environments support STEAM learning in early childhood? A scoping review. *Education Sciences, 14*(6), 627. https://doi.org/10.3390/educsci14060627

UNESCO. (2021). AI and education: Guidance for policy-makers. *UNESCO Publishing*. https://doi.org/10.54675/PCSP7350

Vaisarova, J., Saguid, L., Kupfer, A. S., Goldbaum, H. S., & Lucca, K. (2024). Exploring the creativity-curiosity link in early childhood. *Journal of Creativity, 34*(3), 100090. https://doi.org/10.1016/j.yjoc.2024.100090

Vartiainen, H., Tedre, M., & Valtonen, T. (2020). Learning machine learning with very young children: Who is teaching whom? *International Journal of Child-Computer Interaction, 25*, 100182. https://doi.org/10.1016/j.ijcci.2020.100182

Vella, K., Dobson, M., Rodgers, S., Om, C., Bircanin, F., Dema, T., Pillai, J., Murcia, K., & Brereton, M. (2023). Wired, wild, wonderful: A scoping review of early childhood nature connections fostered by digital technologies. *International Journal of Child-Computer Interaction, 38*, Article 100619. https://doi.org/10.1016/j.ijcci.2023.100619

Verger, N. B., Roberts, J., Guiller, J., & McAloney-Kocaman, K. (2024). Creativity research overlooks the study of resilience among young children: A bibliometric network review. *The Journal of Creative Behavior, 58*(1), 96–113. https://doi.org/10.1002/jocb.632

Xu, Y., et al. (2025). Mapping the ecological landscape of early childhood creativity: A systematic review. *Thinking Skills and Creativity*. https://doi.org/10.1016/j.cogdev.2025.101650

Yang, W. (2022). Artificial intelligence education for young children: Why, what, and how in curriculum design and implementation. *Computers and Education: Artificial Intelligence, 3*, 100061. https://doi.org/10.1016/j.caeai.2022.100061

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. *International Journal of Educational Technology in Higher Education, 16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0

Zucca, C., Smith, L., & Mitra, R. (2023). Outdoor nature-based play in early learning and childcare centres: Identifying determinants of implementation. *Health & Place, 79*, 102955. https://doi.org/10.1016/j.healthplace.2022.102955