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Trends and Patterns in Nature-Based Learning Research in Primary Schools in Indonesia

A Bibliometric Analysis (2015–2025)

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ABSTRACT

Nature-based learning (NBL) is increasingly promoted in Indonesian elementary education to support contextual learning, sustainability, and 21st-century competencies. However, evidence on how the Indonesian research landscape has evolved remains fragmented. This study conducts a bibliometric mapping of NBL research in Indonesian elementary school contexts from 2015 to 2025. Using Publish or Perish with Google Scholar, 598 records were retrieved, merged, and cleaned in Zotero, and refined into 473 journal articles for analysis in VOSviewer. Publication output increased sharply after 2020 and peaked in 2025, indicating rapid growth of the field. Keyword co-occurrence mapping identified six clusters, dominated by environmental education and ecological literacy, teacher and implementation issues, Indonesia-specific context, and model or program development. Overlay visualization suggests a progression from early conceptual framing to impact-oriented studies, and more recently to integration and program implementation. Density mapping reveals that competency-specific outcomes remain underrepresented, particularly in social collaboration and critical thinking, and that implementation quality signals, such as teacher readiness and assessment alignment, appear less frequently than broad environmental themes. These findings clarify current emphases and gaps, and support future work that combines broader database coverage with systematic review and evaluative designs to measure competency development and curriculum integration for teachers, schools, and policymakers.

Keywords
Bibliometric Analysis
Elementary Education
Environmental Education
Indonesia
Nature-Based Learning
VOSviewer

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Introduction

In the past decade, Indonesia's elementary school system has undergone a significant paradigm shift toward a more contextual, participatory, and sustainable approach to learning [1]–[4]. One prominent approach emerging in this context is nature-based learning (NBL). Existing data indicate that NBL has a positive impact on social outcomes and fosters ecological awareness, which is essential for the sustainability of children's futures [5],[6]. NBL emphasizes direct student engagement with their environment, a concept particularly relevant to Indonesia, with its vast natural resources and diverse ecosystems, coasts, mountains, urban forests, and agricultural land [7]–[9]. These resources provide authentic learning materials, enabling students to gain tangible experiences and develop a robust conceptual understanding.

In line with Indonesia's elementary education policies, NBL aligns with the developmental characteristics of elementary-aged children, who, according to Piaget's theory, are in the concrete operational stage [10]–[12]. Children at this stage tend to understand concepts through direct, authentic experiences and physical activities in their surroundings. Edgar Dale's Cone of Experience theory [13], further supports this, stating that the more concrete the learning experiences, the higher students' understanding and retention [14],[15]. Thus, NBL is an effective medium for fostering basic scientific concepts, social values, and environmental awareness.

Theoretically, NBL can develop three core competencies: ecological competence; social and collaborative competence; and critical thinking and problem-solving competence [16]–[19]. These competencies are crucial for students to navigate the complex challenges of the 21st century, particularly in the context of globalization and sustainability. Critical thinking and collaboration are integral to the 6C framework, which includes Critical thinking, Creativity, Collaboration, Communication, Citizenship, and Character [20]. Strengthening ecological competence and social awareness directly supports the achievement of the United Nations Sustainable Development Goals (SDGs), particularly the Planet Pillar [21],[22]. Thus, implementing NBL at the elementary school level is strategically important as it lays the foundation for these global competencies early on.

Ecological competence, defined as the ability to understand the relationship between humans and the environment and act to preserve ecosystems, is particularly significant in primary education [23]–[25]. Fostering ecological competence from an early age is vital for

developing environmental awareness. Primary education plays a crucial role in cultivating a caring attitude toward ecosystems through direct activities in nature [26]–[28]. Research shows that enhancing ecological literacy significantly influences students' environmentally friendly behavior, making NBL an effective medium for achieving sustainable education goals [29],[30]. This aligns with the Adiwiyata program from Indonesia, which positions schools as agents for environmental character-building through contextual learning.

Social and collaborative competence refers to the ability to work together, respect differences, and engage in group activities in outdoor settings [31]–[33]. These competencies are vital for 21st-century learning, enabling students to interact, adapt, and contribute within diverse groups [34]–[37]. Studies show that outdoor collaborative learning experiences enhance empathy, social responsibility, and communication skills [38–40]. NBL offers an authentic setting for developing these competencies, which are less effectively nurtured through traditional classroom instruction [41]. These skills are developed through observation, experimentation, and reflection on natural phenomena.

Furthermore, critical thinking and problem-solving abilities are essential for navigating today's information-rich world [42],[43]. NBL provides a real-world context for identifying problems, devising solutions, and independently evaluating outcomes. Inquiry-based environmental learning models have been shown to enhance significantly critical thinking in elementary students [44],[45]. Thus, NBL not only fosters environmental awareness but also cultivates scientific reasoning and reflective thinking from an early age.

Despite the potential of NBL, its application in Indonesian elementary schools remains sporadic and inconsistent. Although initiatives like Nature School and Adiwiyata serve as models of good practice, many schools still perceive NBL as merely outdoor activities, such as greening or cleanliness competitions, neglecting its cognitive and reflective aspects. The diverse conceptualizations of NBL among teachers have led to a disconnect between outdoor activities and the attainment of 21st-century competencies and SDGs. This gap hinders students from acquiring essential skills to face future challenges and contribute to sustainable development.

Although academic publications on nature-based learning (NBL) in Indonesia have increased markedly in recent years across both conceptual and empirical studies, bibliometric research that systematically maps the patterns, trends, and research directions in this field remains limited. Such mapping is essential because it helps identify dominant research themes, author collaboration networks, and unresolved gaps that can guide future investigations. To address this research gap, the present study conducts a focused bibliometric mapping of NBL research in Indonesian elementary schools, providing a time-sensitive analysis of publications

from 2015 to 2025 that reflects the post-pandemic acceleration of educational innovation. Using VOSviewer, this study also identifies thematic clusters, empirical trends, and research gaps that are often overlooked in narrative reviews; therefore, building on these bibliometric insights, the study formulates three research questions to deepen understanding of NBL in Indonesian elementary education:

RQ1. What are the dominant trends and patterns in NBL research in Indonesian elementary schools between 2015 and 2025?

RQ2. How does NBL research in Indonesia relate to the development of ecological, social-collaborative, and critical thinking competencies in elementary students?

RQ3. What are the challenges and opportunities for integrating NBL into the elementary school curriculum in Indonesia to support the achievement of 21st-century competencies and SDGs?

This study makes three significant contributions. First, it provides a comprehensive analysis of trends and patterns in NBL publications in Indonesian elementary schools from 2015 to 2025. Second, it highlights the crucial role of NBL in fostering competencies such as ecological awareness, social collaboration, and critical thinking, vital for students to address 21st-century challenges. Ultimately, this study offers actionable recommendations for teachers, school leaders, and policymakers to systematically integrate NBL into the curriculum and promote the achievement of the SDGs.

Material and Methods

A. Research Design

This study employs a bibliometric analysis to systematically map the development of nature-based learning (NBL) research in Indonesian elementary school contexts from 2015 to 2025. The bibliometric approach [46], is appropriate for identifying publication growth, dominant research themes and keyword structures, and temporal shifts in topics, which directly support the study's objectives and research questions (RQ1–RQ3). The workflow consisted of three sequential stages: data retrieval using Publish or Perish (PoP) from Google Scholar, metadata screening and cleaning using Zotero, and bibliometric mapping and visualization using VOSviewer (Network, Overlay, and Density) [47],[48].

Google Scholar was selected because it offers broader coverage of Indonesian publications, including nationally disseminated research outputs that are often not indexed in Scopus or Web of Science, thereby enabling a more representative mapping of the domestic research landscape that is consistent with the study's scope.

B. Data Collection and Screening

To improve clarity and transparency of the methodological workflow, Table 1 summarizes the sequential steps used to retrieve publications from Google Scholar via Publish or Perish

(PoP), followed by dataset merging, screening, and metadata cleaning in Zotero, resulting in the final .ris file prepared for VOSviewer analysis.

Table 1. Data Collection, Screening, and Dataset Preparation Workflow

No.	Stage	Tool / Source	Query or Action	Setting / Criteria	Output
1.	Data retrieval	Google Scholar via Publish or Perish (PoP)	Query 1: "pembelajaran berbasis alam" AND "sekolah dasar" AND Indonesia	Export top 200 results ranked by Google Scholar relevance (as returned by PoP)	.ris records (part of 598 total)
		Google Scholar via PoP	Query 2: "nature-based learning" AND "elementary school" AND Indonesia	Export top 200 results ranked by Google Scholar relevance (as returned by PoP)	.ris records (part of 598 total)
		Google Scholar via PoP	Query 3: "environmental education" AND "primary school" AND Indonesia	Export top 200 results ranked by Google Scholar relevance (as returned by PoP)	.ris records (part of 598 total)
2.	Export and compilation	PoP	Export search results	Export format: .ris	598 entries in .ris format
3.	Merging files	Zotero	Merge the three .ris files	Combined into one library for cleaning	Unified dataset (pre-cleaning)
4.	Screening and cleaning	Zotero	Filter document type	Keep journal articles only	Reduced dataset (intermediate)
		Zotero	Remove irrelevant records	Exclude early childhood education focus using keyword filter (e.g., "dini")	Reduced dataset (intermediate)
		Zotero	Remove duplicates	Delete duplicate entries	Clean dataset
5.	Final export for analysis	Zotero	Re-export cleaned dataset	Export format: .ris for VOSviewer input	473 articles in .ris format

C. Data Analysis

The cleaned dataset was analyzed using VOSviewer (v1.6.02) to generate three complementary bibliometric maps based on keyword co-occurrence patterns, providing an integrated view of thematic structure and research evolution [46], [49],[50].

1. Network Visualization was used to identify keyword clusters and their co-occurrence links, revealing the dominant thematic structure of NBL research in Indonesian elementary education. This output primarily addresses RQ1 by highlighting major themes and illustrating how concepts are interconnected across the literature.

2. Overlay Visualization mapped the average publication year of keywords to identify emerging and declining topics over time, directly supporting RQ1 by capturing temporal trends and shifts in research direction between 2015 and 2025.
3. Density Visualization highlighted the most frequently used and least explored keywords, enabling the identification of dominant and underrepresented themes. This supports RQ1 and provides evidence for gaps that inform RQ2 and RQ3.

To address RQ2, the interpretation of clusters and high-density keywords was guided by the competency focus introduced in the study background (ecological competence, social collaborative competence, and critical thinking problem solving). Keywords and clusters were examined for their relevance to these competency domains. To address RQ3**,** clusters and emerging keywords were further analyzed to identify recurring implementation-related issues (e.g., curriculum integration, teacher readiness, program-level practices such as Adiwiyata and nature schools, and broader opportunities and constraints).



Fig. 1. Research Workflow: Data Collection to Results

Fig. 1 summarizes the study's workflow from data acquisition to analytical outputs. The process begins with data collection using Publish or Perish (PoP) to retrieve relevant publications from the selected source based on predefined keywords and the 2015–2025 time window. The retrieved records then undergo data cleaning in Zotero, where metadata are standardized, files are merged, duplicates are removed, and irrelevant documents are excluded to produce an analysis-ready dataset. The final dataset is then processed in VOSviewer, which performs bibliometric mapping based on keyword co-occurrence to reveal the intellectual structure of the field. The workflow generates three core outputs: network visualization to identify thematic clusters and conceptual linkages, overlay visualization to track the temporal evolution of topics by publication year, and density visualization to highlight both dominant and underexplored themes in the literature.

Results

The findings are organized into four sections: Distribution of Articles, Network Visualization, Overlay Visualization, and Density Visualization. The distribution analysis reports the growth of publications on nature-based learning (NBL) in Indonesian elementary schools from 2015 to 2025. Meanwhile, the network, overlay, and density maps reveal the thematic structure, its evolution over time, and the dominant versus underexplored topics based on keyword co-occurrence. Collectively, these outputs address RQ1 by identifying

research trends and patterns, inform RQ2 by situating NBL within competency-related themes in elementary education, and support RQ3 by highlighting implementation-oriented emphases and gaps relevant to curriculum integration and SDG-related outcomes.

A. Distribution of Articles (RQ1)

The trend of research development on nature-based learning in elementary schools in Indonesia shows a significant increase from year to year. The highest number of publications occurred in 2025, with 135 articles. The increase in publications started to be visible since 2020 (36 articles), followed by a rise in 2021 (42 articles), 2022 (49 articles), 2023 (67 articles), reaching its peak in 2024 (92 articles) and 2025 (135 articles). Before 2020, the number of publications remained relatively low, with 19 in 2019, 13 in 2018, 15 in 2017, 3 in 2016, and only 2 in 2015, as illustrated in Fig. 2.

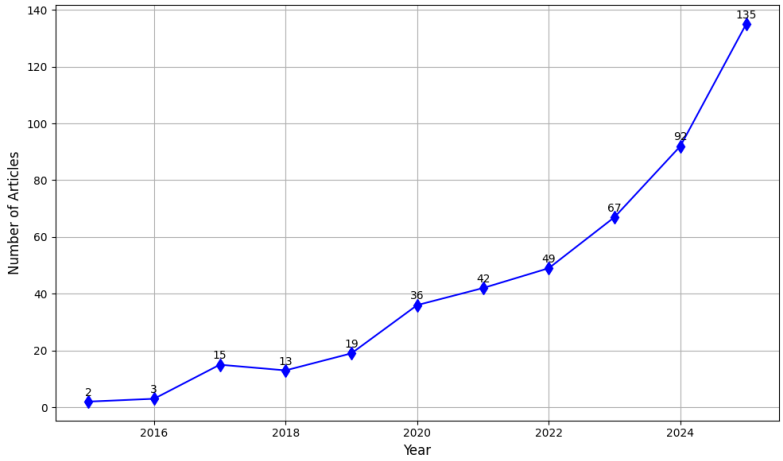


Fig. 2. Distribution of Articles per Year

Fig. 2 depicts the sharp increase since 2020, indicating that NBL has become a rapidly expanding research agenda in Indonesian elementary education. Several contextual drivers may explain this growth:

1. stronger policy attention to sustainable education and the integration of Education for Sustainable Development (ESD) encouraged educators and researchers to explore environment-based learning approaches [51];
2. the Merdeka Curriculum expanded flexibility for contextual learning, which likely stimulated classroom-based studies and implementation-focused publications [52],[53];
3. the COVID-19 period indirectly pushed exploration of outdoor and alternative learning modalities as a response to prolonged online learning constraints [54]–[56]; and
4. increasing publication requirements linked to professional advancement and accreditation. These drivers suggest that publication growth reflects both increasing

academic attention and policy practice dynamics influencing the national research ecosystem.

B. Network Visualization (RQ1, partially RQ3)

The network analysis using VOSviewer identified six thematic clusters in NBL research (see Fig. 3. Overall, the clusters converge around four broad thematic anchors: environmental education and ecological literacy, Indonesia and institutional contexts, teachers and learning implementation, and models or programs supporting NBL in elementary schools. Together, these clusters describe how NBL has been conceptualized, implemented, and discussed across the literature from 2015 to 2025.

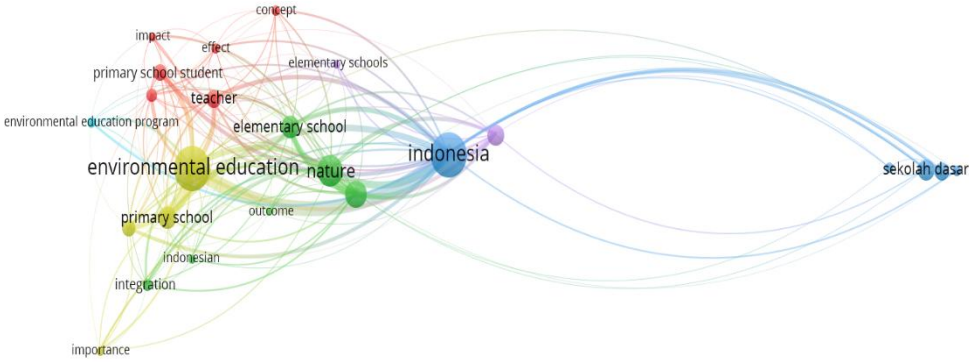


Fig. 3. Network Visualization

1. Cluster 1 (Green): Learning integration and nature as the central concept

Dominant keywords include *elementary school, Indonesian, integration, learning,* and *nature*. In Cluster 1, the topic of nature is the most frequently used item. The topic of nature has 21 relationships with other topics, including environmental education, teacher, model, and nature-based learning. The strength of the relationship on the topic of nature is 342 with 129 occurrences, as illustrated in Fig. 4. This keyword group indicates a research tendency to link nature-based learning with integration of learning and learning outcomes at the elementary school level.

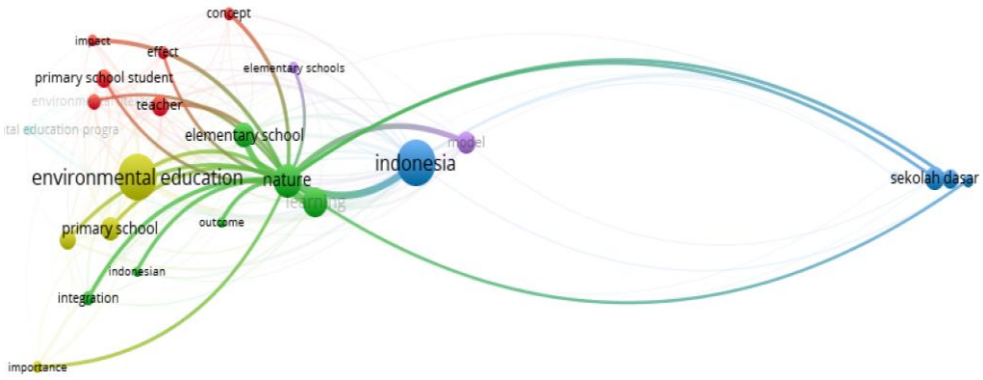


Fig. 4. Network Visualization with the keyword nature

2. Cluster 2 (Red): Teacher role, effects, and environmental literacy outcomes

Dominant keywords include *'teacher,' 'concept,' 'effect,' 'impact,' and 'environmental literacy.'* In Cluster 2, the topic of the teacher is the most frequently used item. The topic of teachers has 17 relationships with other topics, including primary school, integration, learning, and Indonesia. The strength of the relationship on the topic of teacher is 152 with 45 occurrences, as illustrated in Fig. 5. This cluster refers to research focused on the impact of nature-based learning on environmental literacy, learning outcomes, and the role of teachers and student involvement at the elementary school level.

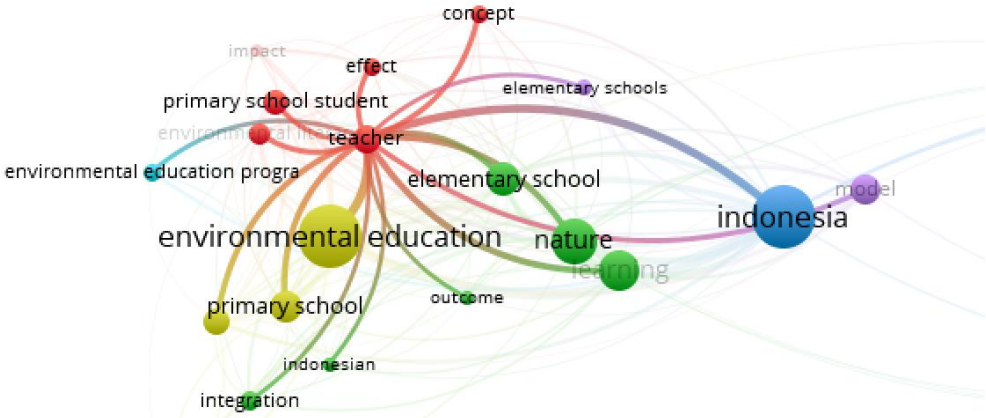


Fig. 5. Network Visualization **with** the keyword teacher

3. Cluster 3 (Dark Blue): Indonesian context and nature school orientation

Dominant keywords include *Indonesia, nature-based learning, nature school,* and *elementary school*. In Cluster 3, the topic of Indonesia is the most frequently used item. The topic of Indonesia has 23 relationships with other topics, including nature, environmental education programs, concept, and elementary schools. The strength of the relationship on the topic of Indonesia is 644 with 252 occurrences, as illustrated in Fig. 6. This cluster highlights the prevalence of themes related to Indonesia's national context, the implementation of nature-based learning, and its connection to the establishment of nature schools at the elementary school level.

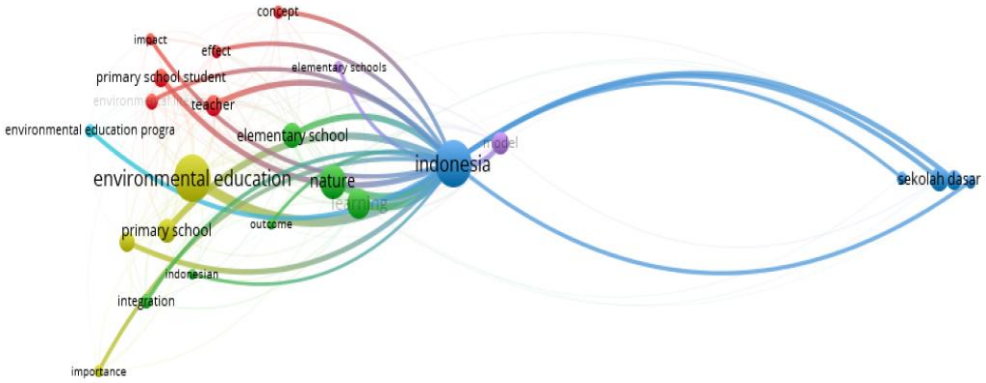


Fig. 6. Network Visualization with the keyword Indonesia

4. Cluster 4 (Yellow): Environmental education and awareness framing

Dominant keywords include *environmental education, awareness, importance,* and *primary school*. In Cluster 4, the topic of environmental education is the most frequently used item. The topic of environmental education has 20 relationships with other topics, including environmental literacy, elementary school, and Indonesia. The strength of the relationship on the topic of environmental education is 579 with 252 occurrences, as illustrated in Fig. 7. This keyword group highlights research focusing on environmental education and the importance of increasing environmental awareness from the elementary school level.

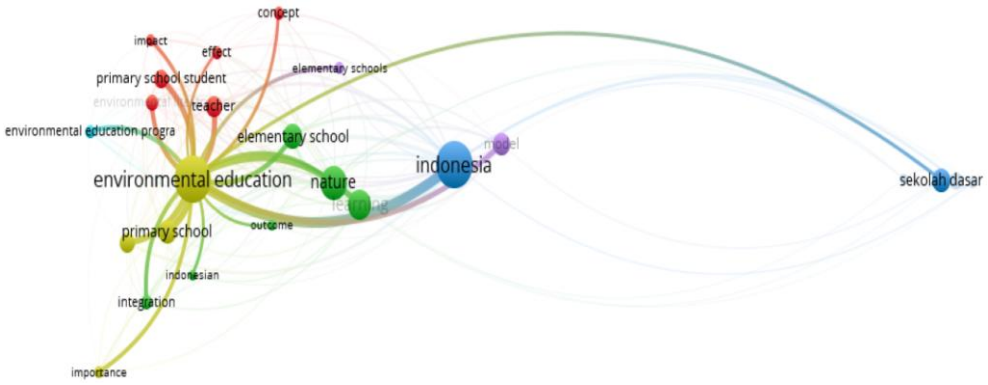


Fig. 7. Network Visualization with the keyword environmental education

5. Cluster 5 (Purple): Model development and instructional design

Dominant keywords include *'model' and 'elementary schools'*. In Cluster 5, the topic of the model is the most frequently used item. The topic of model has 16 relationships with other topics, including nature-based learning, effect, nature, and awareness. The strength of the relationship on the topic of model is 149 with 53 occurrences, as illustrated in Fig. 8. This cluster represents research focused on the development of nature-based learning models implemented in elementary schools.

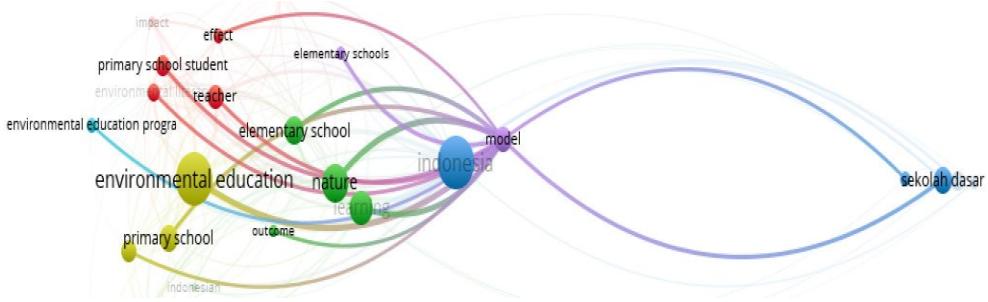


Fig. 8. Network Visualization with the keyword model

6. Cluster 6 (Light Blue): Environmental education programs in school

The dominant keyword includes the *environmental education program*. The topic of environmental education programs has 11 relationships with other topics, including environmental education, elementary school, impact, and Indonesia. The strength of the

relationship on the topic of environmental education program is 44 with 15 occurrences, as illustrated in Fig. 9. This cluster represents studies specifically focused on environmental education programs as part of implementing nature-based learning in elementary schools.

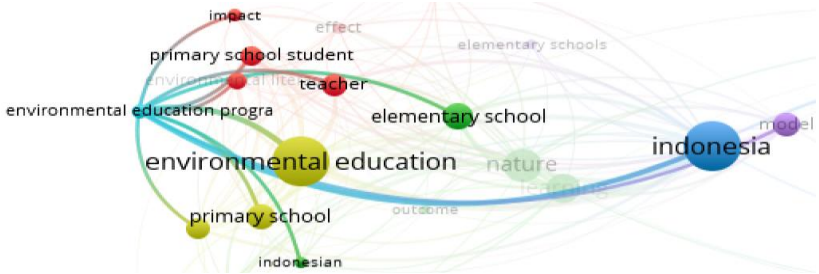


Fig. 9. Network Visualization with the keyword environmental education program

C. Overlay Visualization (RQ1, directional trend that informs RQ3)

Overlay visualization indicates a staged evolution of themes (Fig. 10). Early studies emphasized foundational and contextual keywords such as *environmental education, Indonesia, elementary school, teacher, model,* and *environmental literacy*, suggesting an initial phase of conceptual framing and contextual justification.

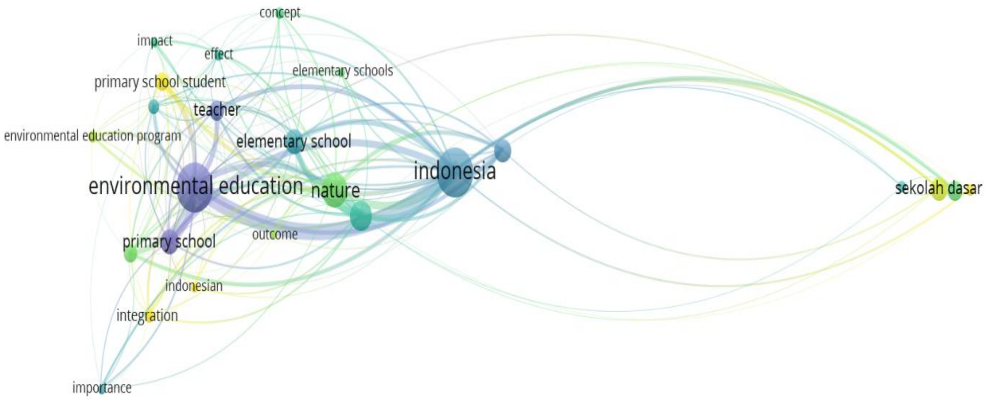


Fig. 10. Overlay Visualization

The middle period shows more evaluative language through keywords such as *impact, effect, outcome,* and *learning*, signaling a shift toward discussing effects, although often not tied to detailed competency measurement. The most recent phase highlights keywords such as *integration, environmental education program, primary school student,* and *nature school*, indicating a trend toward institutional integration and programmatic implementation.

Overall, the overlay results suggest a trajectory from conceptual, contextual framing to impact-oriented discourse, and more recently to integration and program implementation, clarifying the direction of research development over time (RQ1) and signaling increased attention to institutional integration themes relevant to RQ3.

D. Density Visualization (RQ1 and explicit link to RQ2 and RQ3 gaps)

Density visualization highlights the intensity of keyword occurrences to indicate dominant and underexplored topics (see Fig. 11). High-density areas are centered on *environmental education, nature, Indonesia,* and *elementary school*, confirming that the literature is firmly anchored in ecological literacy and contextual framing. In contrast, lower-density keywords such as *importance, awareness, concept, impact,* and *effect* appear less frequently as primary focal points, despite their presence across studies.

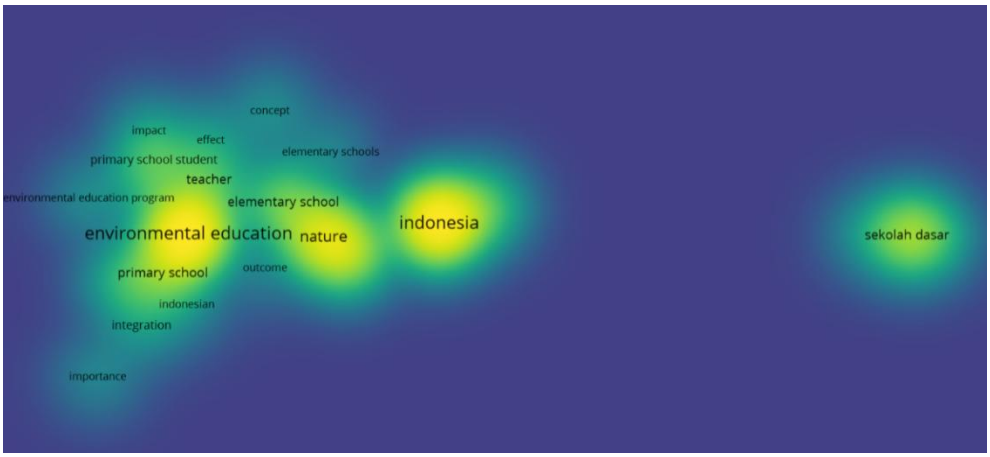


Fig. 11. Density Visualization

Crucially, the density pattern reinforces the research gap introduced earlier: despite rapid growth in publication, research remains concentrated on general environmental education framing, while more specific, competency-aligned, and measurable outcome themes are less intensively developed. This directly informs RQ2 and RQ3 by indicating that the literature still underrepresents: explicit connections between NBL and ecological, social, collaborative, and critical thinking competencies, and systematic studies on curriculum integration quality, teacher readiness, and program effectiveness toward SDG and 21st-century outcomes.

Discussion

The findings indicate a significant increase in NBL-related publications in Indonesian elementary education, particularly since 2020 (Fig. 2). This surge is consistent with the national move toward contextual learning and sustainability orientation under the Merdeka Curriculum and related ESD-driven agendas, which position the environment as a legitimate learning resource [57–60]. The pattern also aligns with experiential learning perspectives that emphasize concrete experiences and reflection as foundations for meaningful learning [61],[62], and with environmental education theory that stresses direct interaction with nature for deeper ecological literacy formation [63],[64]. Significantly, the publication increase is likely shaped by the interaction between curriculum reform, post-pandemic pedagogical

experimentation, and institutional publication incentives, which helps explain why growth accelerated after 2020 rather than developing steadily across the entire decade.

A. Answering RQ1: Dominant trends and patterns (2015–2025)

Across network, overlay, and density results, the dominant pattern is that Indonesian NBL research is thematically anchored in environmental education and ecological literacy, with a strong contextual emphasis on Indonesia and school-level implementation. The network clusters show that teacher roles, integration discourse, and model or program development are recurrent organizing themes, while overlay visualization indicates an evolution from conceptual framing to impact discourse and then to integration and program implementation [65],[66]. Density visualization further confirms that the most dominant research core remains environmental education, along with broad contextual keywords [67]–[69]. Therefore, the field has expanded rapidly but remains structurally concentrated around environmental education framing and school implementation discourse rather than diversified outcome measurement at the learner level.

B. Answering RQ2: Relation to ecological, social, collaborative, and critical thinking competencies

Although the introduction frames NBL as supporting ecological, social, collaborative, and critical thinking competencies, the bibliometric evidence suggests that research emphasis remains uneven across these domains. Ecological competence is the most visible, as evidenced by the strong density of keywords related to environmental education and environmental literacy. In contrast, the relative absence of explicit high-density keywords linked to social collaborative competence and critical thinking indicates that these competencies are less consistently operationalized as primary research focus. In other words, the literature frequently argues that NBL supports the development of broader 21st-century skills. However, the bibliometric structure implies that empirical engagement remains more concentrated on ecological literacy compared with the systematic measurement of social, collaborative outcomes, and critical thinking and problem-solving in elementary learners [34], [70],[71]. This mismatch indicates a substantive gap between the theoretical promise of NBL and the dominant empirical orientation of Indonesian publications.

C. Answering RQ3: Challenges and opportunities for curriculum integration to support 21st century competencies and SDGs

The trend toward integration and environmental education programs indicates an increasing attention to the institutionalization of NBL in schools, which is promising for curriculum integration. However, the network's emphasis on teacher-centered keywords and programmatic terms suggests persistent challenges in implementation quality, including

teacher readiness, consistent pedagogical design, and alignment between outdoor activities and competency-based learning goals [72],[73]. This interpretation is consistent with prior accounts that Indonesian schools may still treat NBL as activity-oriented rather than competency-oriented, resulting in a weak linkage between outdoor practice and targeted learning outcomes. At the same time, the emergence of integration and program-related keywords signals an opportunity to strengthen the systematic embedding of NBL through curriculum design, teacher professional development, and assessment frameworks aligned with the SDGs, particularly the environmental sustainability dimension [74]–[76]. The main opportunity, therefore, lies in shifting from general environmental activity framing toward structured NBL models with measurable outcomes and institutional support mechanisms.

In summary, RQ1 reveals that NBL research in Indonesian elementary schools has expanded rapidly since 2020, with a focus on environmental education-oriented themes, teacher-centered implementation, and program or model development. RQ2 indicates that ecological competence is the most visible competency domain in the literature, while social, collaborative, and critical thinking outcomes remain less explicitly operationalized. RQ3 highlights that an integration discourse is emerging, yet challenges persist in teacher readiness, curriculum alignment, and outcome-based assessment. Nevertheless, these trends open opportunities for strengthening program design and evaluation to support 21st-century competencies and the SDGs.

Implications for Future Research

The density results provide concrete evidence that the field remains concentrated on broad environmental education framing, which explains why research gaps persist in competency measurement and evaluation of implementation. Future research should therefore:

1. operationalize ecological, social collaborative, and critical thinking competencies using clearer indicators and validated assessment approaches;
2. adopt more rigorous evaluative designs to test causal or quasi causal impact pathways rather than relying mainly on conceptual discourse; and
3. examine integration mechanisms at the school level, including teacher training, curriculum alignment, and program governance, to ensure NBL supports both 21st century competencies and SDG-related outcomes.

These steps would shift the field from a thematic concentration toward outcome specificity and implementation robustness, addressing the gaps highlighted by density mapping and aligning research development with the competencies emphasized in the study's theoretical framework.

Conclusion

This bibliometric study mapped the development of nature-based learning (NBL) research in Indonesian elementary schools from 2015 to 2025, utilizing 473 journal articles analyzed through VOSviewer. The findings reveal a significant increase in publications after 2020, suggesting that NBL has become a rapidly expanding research area. Keyword mapping reveals that the field is dominated by environmental education and ecological literacy themes, with a strong emphasis on Indonesia's institutional context, teacher-centered implementation, and program or model development. Overlay results indicate a thematic trajectory from early conceptual framing toward impact-related discourse, and more recently toward integration and program implementation.

Critically, the density map demonstrates that, despite accelerated publication growth, the literature remains concentrated on broad environmental education framing, while outcome-oriented and competency-aligned themes are less intensively developed. This pattern explicitly confirms the research gap identified in the Introduction: NBL research in Indonesia remains limited in systematically linking NBL to the measurable development of ecological, social, collaborative, and critical thinking competencies, as well as in evaluating the quality of implementation for curriculum integration and SDG-oriented outcomes. Therefore, future research should move beyond a descriptive or conceptual emphasis by adopting stronger evaluative designs, clearer competency indicators, and implementation-focused studies that examine teacher readiness, curriculum alignment, and program effectiveness in elementary school settings.

Limitations and Recommendations

This study is constrained by its reliance on Google Scholar (via Publish or Perish) as the sole data source. Although this choice provides broad coverage of Indonesian publications, it may include indexing inconsistencies and does not fully represent NBL studies indexed in Scopus or Web of Science. Additionally, each keyword query was limited to the top 200 results ranked by Google Scholar relevance, which can introduce selection bias because the ranking mechanism is not fully transparent and may not prioritize the most cited or methodologically robust studies.

A further limitation is that the analysis depended mainly on metadata fields (titles, abstracts, and keywords). As a result, the study cannot evaluate methodological depth, research design quality, or the strength of empirical evidence within each article. Although clusters and trends were interpreted through the lens of ecological, social, collaborative, and critical thinking competencies, bibliometric mapping cannot confirm whether these competencies were directly measured, how they were operationalized, or the strength of the

reported effects. Finally, bibliometric visualization is effective for identifying thematic structure and temporal shifts, but it cannot fully explain the causal drivers behind publication growth. It also cannot provide detailed evidence on implementation quality, teacher readiness, and curriculum alignment beyond what is indirectly signaled through recurring keywords.

To strengthen future work, research should broaden its coverage by integrating international databases, such as Scopus and Web of Science, and, where relevant, publisher databases, enabling cross-database comparison and a more comprehensive representation of NBL research in Indonesian elementary education. Future studies should also apply transparent inclusion criteria beyond relevance ranking, for example, through full export when feasible, citation-informed screening, and transparent reporting of the sampling rationale. In addition, bibliometric mapping should be paired with systematic or scoping review procedures that extract study-level methodological details and classify research designs (experimental, quasi-experimental, qualitative, action research). This combined approach would enhance interpretability and facilitate more robust conclusions regarding evidence quality.

Lastly, empirical studies should directly address the gaps suggested by density patterns by operationalizing ecological, social collaborative, and critical thinking competencies using validated indicators and assessment tools, and by prioritizing evaluative designs that test outcome pathways rather than only describing contexts or activities. Implementation-focused research is also recommended to examine curriculum integration mechanisms, teacher professional development, assessment alignment, and program governance (including Adiwiyata and nature school models), so that NBL practice shifts from activity-oriented implementation toward competency-oriented outcomes aligned with 21st-century competencies and SDG-related targets.

Conflict of Interest

The authors declare no conflict of interest.

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