



## Systematic Review of Research Trends in Environmental Literacy in Primary and Secondary Education: A Bibliometric Analysis 2016-2025

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### Abstract

The latest Programme for International Student Assessment assesses competencies in the context of environmental issues, making the strengthening of environmental education crucial for enhancing students' environmental literacy. This study aims to analyze the trends, implementation, and dominant topics of environmental literacy in primary to secondary education. A systematic literature review (SLR) was conducted following the PRISMA protocol. A primary data search was performed on the Scopus database using the keyword "environmental literacy" for the 2016-2025 period, which yielded 22 journal articles that met the inclusion criteria. The analysis results show that environmental literacy is measured through four domains: knowledge, skills, attitudes, and responsible behavior. The most dominant measurement method was questionnaires, while the learning approaches included educational games, environmental projects, and problem-based models. The collaboration of activities, surveys, models, and learning media can enable the measurement of environmental literacy to fulfill its domains. Environmental literacy is increasingly oriented towards environmental education and environmental issues, considering effectiveness, awareness, behavior, and learning models. Effective implementation must integrate problem-based learning models that connect local environmental issues with indigenous wisdom, alongside interactive media and educational projects. This study contributes by emphasizing the balance between assessment and authentic learning experience for environmental literacy aligned with Programme for International Student Assessment competencies.

### How to Cite

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## INTRODUCTION

The 2022 PISA results indicate that Indonesia's ranking improved by 5-6 positions compared to PISA 2018; however, reading literacy scores declined to 359 points, representing the lowest record since 2000. According to the PISA 2025 data from the OECD PISA Framework, the focus is on education concerning sustainability and environmental education. Previous environmental awareness and environmental optimism have been modified and expanded to include environmental awareness, environmental concern, and environmental agency (OECD, 2025). PISA 2025 assesses competencies and knowledge within specific contexts that raise issues and choices relevant to science and environmental education.

Amid increasing climate change, biodiversity loss, and other urgent socio-ecological problems, the key to stemming and solving the greatest challenges of our time requires the engagement of individuals and communities (Wheaton et al., 2024). Ecological knowledge is one component of environmental literacy that refers to people's ability to understand and apply acquired knowledge about ecology to achieve an understanding of how nature works and its interactions with social systems (Celades et al., 2021).

Based on the identified environmental problems, it is necessary to develop environmental education for students to enhance environmental literacy. Environmental literacy refers to an individual's understanding of everything related to the environment, including knowing existing problems and being able to seek solutions and address environmental issues in their surroundings (Utami, 2019). Environmental literacy has also become one of the aspects that must be developed in 21<sup>st</sup> century education (Stehle & Peters-Burton, 2019).

Environmental literacy first emerged as a goal of environmental education in the 1960s to 1970s. Environmental literacy theory assumes that environmentally literate individuals possess adequate knowledge and attitudes and behave in environmentally friendly ways (Svobodová & Kroufek, 2022). The North American Association for Environmental Education (NAAEE) defines environmental literacy as encompassing awareness and concern for the environment and related issues, knowledge, skills, and the desire to find new preventive actions and solutions to existing environmental problems (Hollweg et al., 2011). Environmental literacy includes knowledge, attitudes, sensitivity, and responsible environmental behavior (Svobodová, 2023).

Students with environmental literacy will behave responsibly toward the environment through knowledge, skills, and awareness of environmental issues, thus environmental literacy plays a role in shaping an individual's character to care for the environment (Febriasari & Supriatna, 2017). Environmental literacy is an important part of sustainable education. Integrated, innovative, and technology-based pedagogical approaches are required to support and ensure success of sustainability education in secondary schools (Andriansyah et al., 2025). Through implementation of sustainable development goals in education, research, and outreach, education should become a strategy for advancing sustainable development (Lovren & Jablanovic, 2023).

The balance between fulfilling human life needs and environmental preservation must be a shared goal to ensure the sustainability of future life in accordance with the Sustainable Development Goals (SDGs) agenda. The Education for Environmental Sustainable Development (EESD) approach can be applied in science education to provide students with valuable insights about the environment (Wilujeng et al., 2019).

Environmental literacy has become a critical issue amid global challenges such as climate change, deforestation, and pollution. As a foundation for building awareness and sustainable action, research on environmental literacy has grown rapidly in last decade, involving multidisciplinary fields such as education, environmental psychology, public policy, and green technology.

A relevant bibliometric analysis study on environmental literacy using the Scopus database from 2013 to 2023 reveals the relationship between concepts, themes, and research areas regarding the nature of environmental literacy within the broader context of sustainable development. Insights gained from this research advance knowledge and take action to promote the role of literacy in sustainable development that addresses environmental literacy gaps through higher education learning (Ariyatun et al., 2024).

Based on the previously explained background, a systematic and comprehensive study is needed to identify research trends in environmental literacy in primary and secondary education. The study aims to identify various activities that can be conducted to measure environmental literacy in primary and secondary education, analyze development of environmental literacy research trends in primary and secondary education over last 10 years, identify dominant topics in environmental literacy research educational contexts and interrelationships, while providing recommenda-

tions for future research on environmental literacy in primary and secondary education.

These objectives can be achieved by conducting an in-depth analysis based on the Scopus database to provide a comprehensive overview of environmental literacy. This is accomplished through bibliometric analysis using Systematic Literature Review (SLR) method and VOSviewer software. Through this analysis, insights are gained regarding differences in patterns of activities conducted to measure environmental literacy through learning in primary and secondary school students. Furthermore, method can identify trends, topics, and relationships between research topics surrounding environmental literacy.

This research represents an innovation compared to previous studies on environmental literacy using the Scopus database. The novelty of this research includes extended analysis years, educational levels covering primary and secondary education rather than higher education, and the research focuses on implementing activities to measure environmental literacy conducted in schools and research trends as well as relationships between dominant topics from the analysis results, not merely linking it to sustainability education alone.

The benefits of this study help researchers, policymakers, and practitioners understand the current state of environmental literacy research by identifying effective activities that can be conducted to measure environmental literacy, analyzing the development of environmental literacy research by year, dominant topics related to environmental literacy and their interrelationships for future directions in advancing environmental literacy in primary and secondary education.

## METHOD

This study employs the Systematic Literature Review (SLR) method, conducted through several systematic stages to explore publications related to the implementation of environmental literacy in science education. This SLR aims to collect, analyze, and interpret research findings pertaining to the research topic (Li et al., 2025). Data collection refers to PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which include identification, screening, eligibility assessment, and inclusion. The entire literature search procedure was completed in May 2025. Article publication searches through the Scopus database, as this source contains journal articles considered more

relevant by the scientific community (Sahrir et al., 2024).

The research commenced on March 25, 2025, through the Scopus database using the keyword "Environmental Literacy," which yielded 945 articles. To ensure that only research relevant to our topic was selected from the database, specific inclusion and exclusion criteria were established (Hidayat et al., 2025). The initial identification results proceeded to the screening stage to ensure the articles met the inclusion criteria. The inclusion criteria for the analyzed articles can be seen in Table 1.

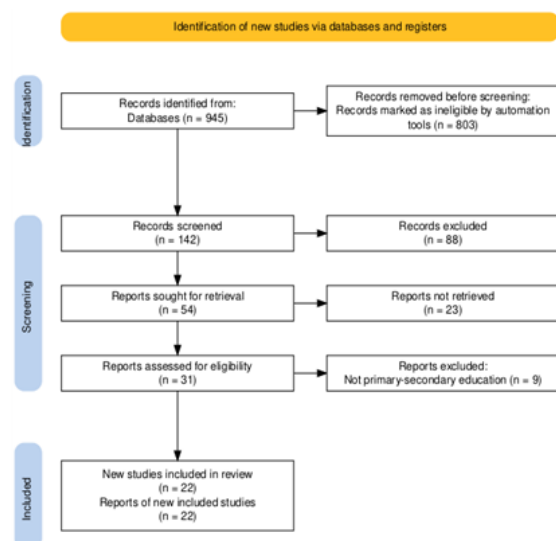
**Table 1.** Guidelines for Inclusion Criteria for Journal Selection

| Category          | : Inclusion Criteria                       |
|-------------------|--------------------------------------------|
| Database          | : Scopus                                   |
| Year              | : 2016 - 2025                              |
| Subject Area      | : Social Science and Environmental Science |
| Research Subjects | : Students/Learners                        |
| Document Type     | : Research Journal Articles                |
| Language          | : English                                  |
| Access            | : Open Access                              |

After screening based on the inclusion criteria, 142 articles remained. The articles were analyzed based on their abstracts, resulting in 31 articles that met the criteria for environmental literacy in education. Through the Systematic Literature Review method, articles were analyzed based on full texts containing discussions about environmental literacy in education at elementary, junior high, senior high, and vocational school levels, yielding 22 articles. The final results synthesized articles to examine research trends over last 10 years and provide recommendations for future research on environmental literacy in education. Overall, the article selection mechanism using PRISMA can be seen in Figure 1.

The synthesized article data were analyzed using VOSviewer to generate graphical representations of bibliometric maps, which facilitate researchers in assessing and interpreting bibliometric maps due to their readable display (Tang et al., 2018). The data were visualized using VOSviewer tool with the final results from article synthesis documented in (.ris) format for visualization processing. Visualization was performed on downloaded metadata stored in RIS format based on the VOSviewer software algorithm (Putri et al., 2021). Visualization analysis was used to exami-

ne research trends over the last 10 years, dominant topics, inter-topic relationships, and recommendations for future research on environmental literacy in primary and secondary education.



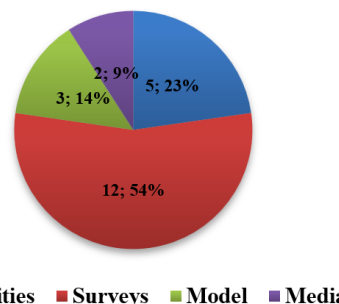
**Figure 1.** Article Selection Mechanism Using PRISMA

## RESULT AND DISCUSSION

This study presents findings addressing the research questions by examining several articles concerning environmental literacy in education, spanning from primary to secondary school levels. This constitutes a crucial step in understanding the development of environmental literacy research, which contributes significantly to scholarly literature in the field of education.

### Environmental Literacy in Primary and Secondary Education

Education plays a vital role in shaping an environmentally conscious and responsible generation. As environmental challenges intensify, environmental awareness and sustainable development concepts have progressively emerged as international concerns. Specifically, environmental issues gaining global attention are directing environmental education objectives toward social prospective dimensions (Chen et al., 2020). Currently, it is particularly important to explore research on environmental literacy education and sustainable development in schools based on teaching effectiveness (Huang & Hsin, 2023). Environmental literacy education aims to provide a deeper understanding of the relationship between humans and the natural environment and how the impact of human actions can affect the Earth.



**Figure 2.** Analysis of Environmental Literacy Measurement Implementation

The pie chart in Figure 2 illustrates the proportional contributions made by various researchers in measuring environmental literacy using different types of assessment methods. The survey category was most frequently employed to measure environmental literacy among students from primary to secondary education levels without prior intervention. Environmental literacy was assessed using questionnaires containing aspects related to both education and environment. Additionally, there were questionnaires measuring integration, 4C skills (Critical Thinking, Creativity, Collaboration, Communication), demographic data, and PISA instruments. The measurement of environmental literacy was discussed across three domains: the knowledge domain, environmental attitudes, and environmental behavior (Putra et al., 2021).

The majority of environmental literacy assessments indicate that the knowledge domain or aspect is more dominant or prominent. This aligns with research conducted by Lovren & Jablanovic (2023), where learning outcomes in primary and secondary education show cognitive dominance compared to affective and behavioral dimensions. However, this does not preclude the possibility of other aspects being dominant, such as environmental attitudes and behaviors. This is because the affective and behavioral dimensions of environmental literacy are interconnected and proven to be significant (Svobodová & Kroufek, 2022). Secondary school students demonstrate significant environmental literacy that strongly correlates with environmental behavior (Chao, 2024). Attitudes and sensitivity can be considered crucial determinants of responsible environmental behavior (Svobodová, 2023). Although these three aspects of environmental literacy are interconnected, some aspects remain less dominant in addressing environmental problems. Environmental problem mitigation remains inadequate at the level of environmental literacy in the action aspect (Maknun et al., 2018).

Education and awareness represent the most effective strategies for addressing environmental issues (Goel et al., 2023). Environmental issues are also closely related to environmental literacy measurement, serving as topics discussed in research instruments. Students understand several environmental problems and related issues, but their awareness levels vary across different environmental issues (Ndzimbomvu et al., 2021). Most students do not change their positions after reading additional contrasting information presented as evidence regarding environmental issues (Emery et al., 2017). The level of environmental literacy possessed by individuals or organizations can help determine their perspectives on environmental issues (Mujib et al., 2023).

Surveys conducted to measure students' environmental literacy do not only assess environmental literacy aspects. However, they are also associated with other aspects such as 4C skills and demographics. Formal and regulated environmental literacy, along with digital literacy, significantly contribute to the enhancement of mathematical thinking skills (Farida et al., 2023) [WU2.1][HL2.2]. Demographics here serve as external factors that can influence students' environmental literacy aspects. Environmental literacy is shaped through family environment, socioeconomic status, environmental education, school infrastructure, and several other factors (Edsall & Broich, 2020). The role of stakeholders and the availability of green open spaces in schools support students' environmental literacy (Putra et al., 2021).

Environmental literacy measurement is not only conducted through surveys using questionnaires related to environmental literacy aspects. Various activities can be implemented first to enhance students' environmental literacy capabilities before measurement. Through the "tragedy of the commons" game, not only is theoretical understanding strengthened, but it also triggers more ambitious goal setting and sustainable behavioral changes by supporting the integration of interactive educational methods (Igei et al., 2024). Another game, "Eko Game," uses gamification learning technology as a mechanism to facilitate the enhancement of ecological literacy, indigenous knowledge, and pro-environmental behavior (Reihana et al., 2019).

There are other activities besides games that have been implemented, such as school programs or projects with broad student reach. One-day environmental education programs have long-term positive effects on environmental attitudes, knowledge, and actions (Pan & Hsu,

2020). ESD was successfully transformed by the Low Carbon School Community program, thereby improving students' environmental literacy (Mahat et al., 2020). The GAIA (Green Awareness in Action) class project yielded learning effects that correlated well with pro-environmental preferences in conservation, but low in utilization (Maurer et al., 2020).

Learning models applied by teachers in learning activities can also influence students' capabilities in understanding environmental literacy. Problem-based learning with local wisdom oriented toward socio-scientific issues significantly impacts conceptual knowledge and environmental literacy (Lubis et al., 2022). The integration of local wisdom into science learning not only enriches content but also fosters meaningful engagement and sustainability values (Nurmasitoh et al., 2025).

The implementation of learning models found were all related to local contexts such as local culture or traditional activities. Blended learning models relevant to Indonesian educational trends and curriculum are needed to enhance students' environmental literacy while considering local socio-cultural aspects (Hermawan et al., 2022). Various learning models improve students' understanding of environmental problems although the effect levels differ (Lestari et al., 2024).

Learning media are used as aids to help students understand materials related to environmental literacy more interactively. Learning media here include student worksheets. EESD-based student worksheets are beneficial for improving students' environmental literacy, and problem-based learning models oriented toward socio-scientific issues become effective and efficient means (Wilujeng et al., 2019). LE-PBL student worksheets strengthen students' environmental literacy in identifying, analyzing, evaluating, and planning actions, as well as sensitivity toward local and global environmental issues (Suryawati et al., 2020). In line with the research conducted by Nurmasitoh et al. (2025), contextual science education, grounded in local wisdom and supported by interactive digital media, can serve as a powerful tool for enhancing critical thinking and environmental literacy.

Based on explanations and findings, interventions that can be implemented to measure environmental literacy in primary and secondary education include activities, surveys, learning models, and learning media. These activities lead to interactive learning activities such as learning games or projects that can be conducted in pairs or groups. These activities can measure not only

students' environmental literacy in terms of knowledge but also attitudes, skills, and environmental behaviors. Meanwhile, environmental literacy measurement using surveys mostly assesses students' understanding in terms of knowledge, as attitudes, skills, and environmental behaviors cannot be measured and observed directly.

Learning models and media in measuring environmental literacy serve as supporters with interconnections to achieve learning activities according to learning objectives. Learning models and media can be used in planned learning activities or activities. Models refer to stages to be implemented by teachers and students, while media serve as learning aids to facilitate students' understanding of environmental literacy.

Environmental literacy can be measured using surveys, but it still requires activities that students must undertake, complemented by learning models and media that support understanding and activities directed toward environmental literacy. Collaboration between activities, surveys, models, and learning media can ensure that environmental literacy measurement fulfills the intended domains: knowledge, attitudes, skills, and environmental behaviors.

### Research Trends in Environmental Literacy in Primary and Secondary Education

Environmental literacy in the education field over the last 10 years was analyzed using VOSviewer. Overlay Visualization analysis displays the average appearance time of each term based on publications indicated by research

trend colors from year to year. The color scale shows the average publication year in which these terms most frequently appeared. The color scale at the bottom shows the time range from 2021.0 to 2022.0. Light purple/blue colors indicate older publications, while green/yellow colors indicate newer publications.

The terms "Education," "Action," "Environment," "Test," and "Environmental Literacy" tend to have colors ranging from purple to bluish. Referring to the color scale, this means these terms appeared more frequently in the early to middle period of the analyzed time range, approximately 2021.0 – 2021.4. This indicates that these concepts have been foundational discussion topics for a longer period or have consistently appeared throughout the analyzed timeframe. Terms such as "Effectiveness," "Awareness," "Model," "Environmental Education," "Environmental Issue," and "Attitude" indicate newer publications approaching 2022.0. This suggests an increased focus on the application, impact, or evaluation of environmental literacy in recent years. This visualization provides insights into the evolution of these terms and helps identify research trends. It appears that research focus in environmental literacy has shifted from basic concepts toward more specific aspects with broader scope. Further research can focus on specific aspects of environmental literacy, such as ecosystem understanding, environmental conservation actions, or awareness of global issues (Lestari et al., 2024).

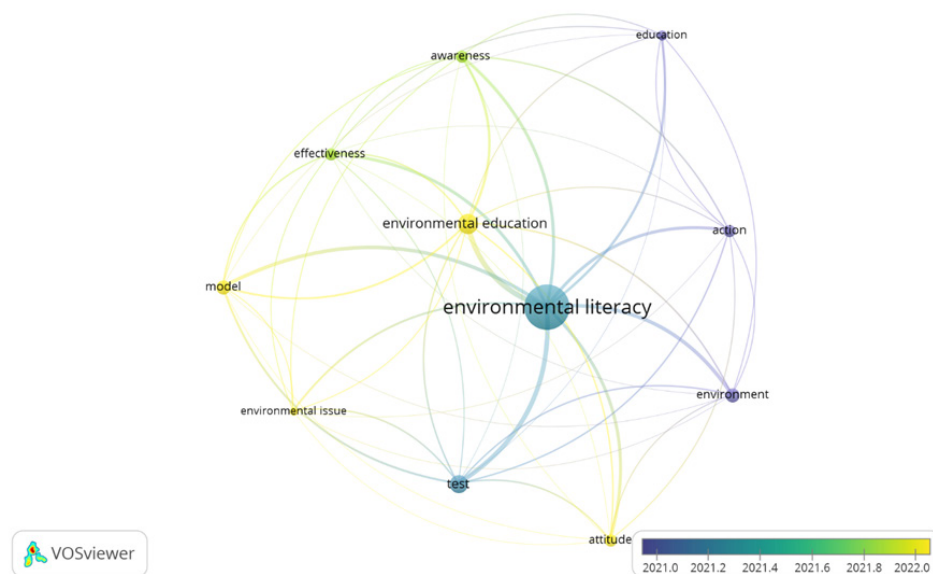


Figure 3. Research Trend Visualization Based on Year

The terms "Education," "Action," "Environment," "Test," and "Environmental Literacy" tend to have colors ranging from purple to bluish. Referring to the color scale, this means these terms appeared more frequently in the early to middle period of the analyzed time range, approximately 2021.0 – 2021.4. This indicates that these concepts have been foundational discussion topics for a longer period or have consistently appeared throughout analyzed timeframe. Terms such as "Effectiveness," "Awareness," "Model," "Environmental Education," "Environmental Issue," and "Attitude" indicate newer publications approaching 2022.0. This suggests an increased focus on the application, impact, or evaluation of environmental literacy in recent years. This visualization provides insights into the evolution of these terms and helps identify research trends. It appears that research focus in environmental literacy has shifted from basic concepts toward more specific aspects with broader scope. Further research can focus on specific aspects of environmental literacy, such as ecosystem understanding, environmental conservation actions, or awareness of global issues (Lestari et al., 2024).

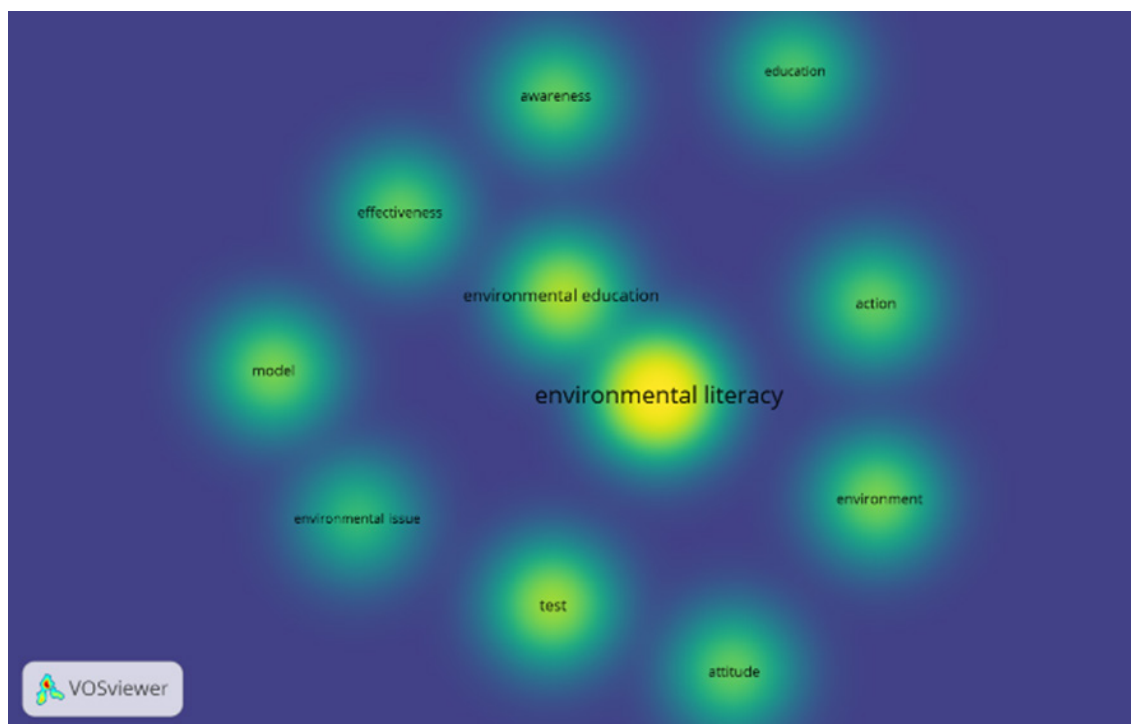
Based on VOSviewer analysis findings, environmental literacy is increasingly oriented toward environmental education and environmental issues while considering effectiveness, awareness, behavior, and learning models. These topics will become research trends in environmental

literacy primary and secondary education. The National Environmental Literacy Assessment in US distinguishes four components environmental literacy: ecological knowledge, cognitive skills, environmental impact, and pro-environmental behavior (Lovren and Jablanovic, 2023).

#### **Dominant Topics in Environmental Literacy for Primary and Secondary Education**

Analysis of Density Visualization shows density patterns visible in Figure 4, indicating areas with high term or topic density. The brighter the color (yellow), the higher the density of terms or topics in that area, meaning these topics frequently co-occur or are highly relevant to each other.

Environmental literacy appears as a core or central topic that has been extensively researched, as indicated by the bright yellow color. The highest brightness is around "environmental literacy," confirming its role as a dominant topic. Surrounding "environmental literacy" includes "environmental education," indicating a very strong relationship between environmental literacy and environmental education. Other circles encompassing "awareness," "effectiveness," "model," "environmental issue," "test," "attitude," "education," "action," and "environment" indicate that these concepts have significant connections with environmental literacy and environmental education.



**Figure 4.** Dominant Topic Visualization in Environmental Literacy Based on Density

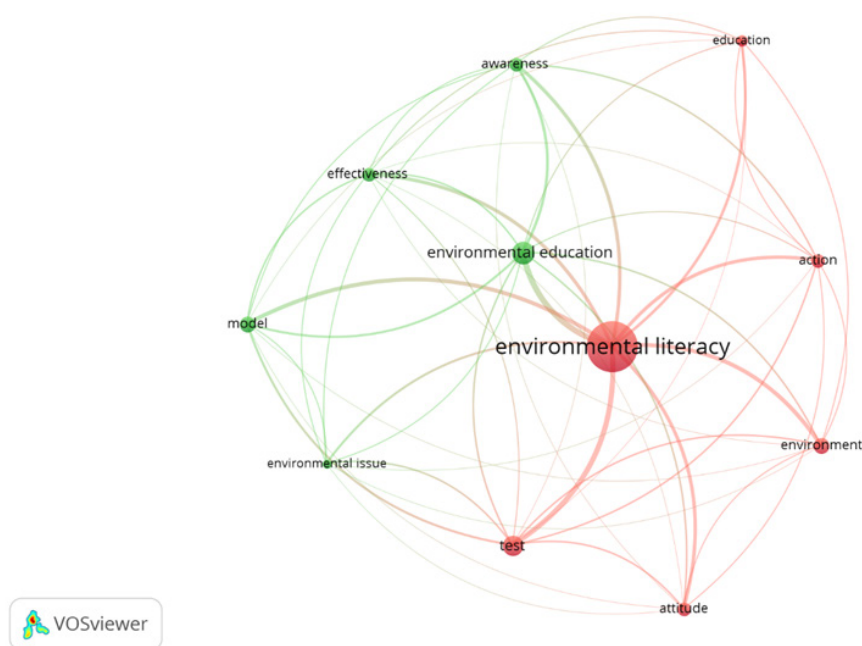
This visualization helps identify key topics and sub-topics most frequently discussed and having strong interconnections in environmental literacy literature. This analysis provides a comprehensive overview of the research landscape and discussions surrounding environmental literacy, highlighting inter-conceptual relationships and developmental trends over time. Environmental Education has emerged as an important strategy aimed at enhancing students' environmental literacy such as awareness, knowledge, and attitudes toward the environment (Lee & Kang, 2023).

Based on VOSviewer analysis findings regarding topic density in environmental literacy, environmental literacy and environmental education are mutually interconnected. Therefore, environmental literacy is part of environmental education that can be collaborated with various other topics. Environmental issues have low density or haven't been extensively researched in connection with environmental literacy or environmental education. Environmental issues can provide novelty in analyzing environmental li-

teracy while still considering the main domains of environmental literacy. The main domains of environmental literacy encompassing knowledge, attitudes, skills, and responsible environmental behavior are also included in frequently discussed topics related to environmental literacy. Environmental issues can serve as discussion topics before measuring environmental literacy to introduce students to the concepts.

### Interrelationships Among Dominant Environmental Literacy Topics in Primary and Secondary Education

Furthermore, Network Visualization shown in Figure 5 displays the connectivity of emerging terms. Each circle represents a term or keyword, and the circle size indicates the frequency of term occurrence. Lines connecting circles show relationships or co-occurrence between terms. The thicker the line, the stronger the relationship between two terms. Line colors (green and pink) indicate different clusters or conceptual groups.



**Figure 5.** Inter-topic Relationship Visualization in Environmental Literacy

VOSviewer often groups circles based on their relationships into different colored clusters. The "Environmental literacy" term has the largest circle, supporting its status as the main concept. The Red Cluster centers around "environmental literacy," consisting of terms "action," "environment," "attitude," "test," and "education."

This represents basic aspects of environmental literacy, its impacts, and measurement, showing focus on environmental literacy assessment. The Green Cluster includes "environmental education," "awareness," "effectiveness," "model," and "environmental issue," representing process and context aspects of environmental literacy and en-

vironmental education. "Environmental education" and "awareness" have strong connections. This aligns with research by (Goel et al., 2023) that education and awareness are most effective strategies for addressing environmental problems.

This network visualization reveals the relationship structure between topics from each emerging term. It appears that "environmental literacy" functions as a central connector between basic concept-oriented topics and outcome/measurement topics in the red cluster, and process and input-oriented concepts in the green cluster. Environmental education aims to create humans with good environmental literacy (Putra et al., 2021).

### **Future Research on Environmental Literacy in Education**

Environmental literacy in education is closely related to environmental education. The latest PISA 2025 data from the OECD PISA Framework focuses on sustainability education and environmental education. Through SLR (Systematic Literature Review) findings and visualization analysis using VOSviewer, researchers can recommend several topics that can serve as references for future research related to environmental literacy. Environmental literacy has become a central focus and is strategically important to study in the context of environmental education. Environmental education is the main means for building environmental literacy. Topics such as "awareness," "effectiveness," and "model" are frequently discussed in the context of how environmental education can be designed and evaluated.

Environmental Literacy as a core topic with main objectives or expected outcomes. Research centers on understanding, developing, and measuring environmental literacy. Increasing research focuses on outcomes of environmental literacy, such as behavioral changes (action), development of positive attitudes (attitude), environmental awareness (awareness), and how this literacy can be measured (test) and its impact on the environment (environment) and education (education). Recent trends show increased focus on these aspects.

Environmental Issues are drivers or contexts explaining why environmental literacy is important, and how environmental education is designed to address these issues. In summary, "environmental literacy" is the main pillar, supported by "environmental education," and evalu-

ated through "action," "attitude," "awareness," and "test," with "environmental issue" as the background and driver of its relevance. Current trends also show a shift toward application and impact aspects of environmental literacy. Student activities are also encouraged to meet 21st-century learning demands by implementing environmental literacy, making environmental issues an effective alternative learning approach.

Environmental education is the main means for building environmental literacy. Concepts like "effectiveness" and "model" are frequently discussed in the context of how environmental education can be designed and evaluated. Using learning models can influence the improvement of students' environmental literacy capabilities. Learning should be more applicable and efficient while playing a broad role in supporting the realization of students' environmental literacy capabilities. Supporting national sustainable development goals while not forgetting technology in offering innovative solutions, such as virtual laboratory simulations and digital-based experiments, which can overcome educational infrastructure limitations, especially in schools without laboratory facilities (Priyadi et al., 2025).

Future research on environmental literacy will generally continue to advance annually. Implementing and collaborating on various elements to measure and observe improvements in students' environmental literacy capabilities. Environmental literacy is closely related to environmental education in schools, so measuring environmental literacy requires attention to existing aspects. Aspects of environmental literacy measurement are all interconnected with each other. These aspects also become dominant topics and recent terms that frequently appeared in recent years.

Environmental literacy is closely related to existing environmental problems in local, national, and even global contexts, so environmental issues need attention in measuring environmental literacy. Learning activities implementation requires attention as they can influence students' environmental literacy capabilities. Implementing various activities, models, and media in learning can make learning more interactive, thereby improving students' environmental literacy capabilities. Developing innovative ESD (Education for Sustainable Development)-based learning models, utilizing gamification, and multi-stakeholder collaboration to support the formation of a more environmentally conscious generation.

## CONCLUSION

This systematic review concludes that environmental literacy in primary and secondary education cannot be achieved through measurement alone; it requires a holistic pedagogical approach. Effective implementation must integrate problem-based learning models that connect local environmental issues with indigenous wisdom, alongside interactive media and educational projects. These activities serve as essential stimuli to ensure that measurement of environmental literacy comprehensively covers its core domains: knowledge, attitudes, skills, and responsible behaviour. The contribution of this study lies in emphasizing that environmental literacy efforts must balance assessment (surveys) with authentic learning experiences. This approach not only supports the framework of environmental education but also aligns with the competencies assessed in PISA 2025. Future research should adopt a more holistic perspective by strengthening the affective and behavioural dimensions, integrating technology and local wisdom, and evaluating the long-term impact of environmental literacy programs.

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