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Ecoliteracy in Early Childhood Education: A Systematic Literature Review of Construct, Pedagogy, and Assessment

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Abstract: This review examines how ecoliteracy is defined and dimensioned in early childhood education research, which learning strategies are used to foster it, how children are assessed, and what trends and gaps appear. Following PRISMA 2020, Scopus records published between 2016 and 2026 in the Environmental Science subject area were searched in five steps (1,208 records). Twenty-two journal articles were read in full text, appraised with the Mixed Methods Appraisal Tool, and synthesized through structured thematic analysis. No study takes ecoliteracy as its principal term, and the term is absent from all 144 articles screened before the keyword limit; environmental education is the most frequent of twelve terms. Eleven studies examine nature-based outdoor learning. Ten studies do not assess children, and the four that use a scored instrument or a rubric use four different instruments. A restraint dimension is stated explicitly in only one study, and three countries contribute 14 studies. Within the reviewed corpus, the construct is used without a shared name, set of dimensions, or instrument. This study proposes a framework spanning cognitive, affective, action, ethical, and restraint dimensions as a basis for early childhood ecoliteracy instruments.

Keywords: early childhood education, ecoliteracy, environmental education, sustainability, systematic literature review.

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INTRODUCTION

Global commitments to sustainability have placed education at the center of the response to environmental degradation. Target 4.7 of the Sustainable Development Goals requires all learners to acquire the knowledge and skills needed to promote sustainable development. However, monitoring studies show that its translation into curricula, educator training, and student assessment remains uneven across countries (Holst et al., 2024). Comparative analyses of national early childhood curricula confirm this unevenness, showing that sustainability is embedded in markedly different ways even among countries with similar policy commitments (Melis et al., 2026). Early childhood occupies a strategic position within this agenda. Research on children's relationships with the natural world indicates that dispositions formed in the first years of life, particularly emotional connection to living things and the sense that one's own actions matter, are associated with pro-environmental commitment later in the life course (Chawla, 2020). Environmental learning at this stage is therefore not preparation for a later curriculum but the formation of the dispositions on which any later curriculum depends. What remains contested is not whether young children can engage with sustainability, but how that engagement should be conceptualized, cultivated and recognized.

Ecoliteracy is one construct used to name that engagement. Unlike environmental knowledge, ecoliteracy is understood as the capacity to grasp how living systems work, together with the willingness to act on that understanding. McBride et al. (2013) demonstrate, however, that ecoliteracy,

ecological literacy and environmental literacy have circulated as near synonyms while carrying markedly different theoretical commitments, and that this terminological drift has hindered the accumulation of evidence. The boundary between the two most common terms can nonetheless be drawn. Environmental literacy has usually been framed as a set of knowledge, attitudes, skills and behaviors concerning environmental issues, and its stronger versions extend literacy to a capacity to read the environment critically (Stables & Bishop, 2001). Ecological literacy, and its shortened form, ecoliteracy, starts with an understanding of how living systems are organized through interdependence, cycles, and change over time, and treats that understanding as the ground on which care and responsible action are built (Cutter-Mackenzie & Smith, 2003; McBride et al., 2013). In the early years, the difference is practical rather than semantic. An environmental literacy lens asks what a child knows or does about an environmental issue, such as sorting waste correctly. In contrast, an ecoliteracy lens asks whether the child perceives the relations among living things and acts within them, for instance by noticing that a plant in the classroom needs water, caring for it, and using no more water than it needs. The second lens therefore requires ethical and restraint-oriented dimensions that the first can leave implicit. Frameworks that operationalize the construct commonly span cognitive, affective, and behavioral domains, as in the head, hands, and heart formulation advanced by Sipos et al. (2008). In early childhood, the stakes of this ambiguity are higher than elsewhere, because children of this age express understanding through action, play and talk rather than through written or formal verbal reasoning. A construct defined predominantly in cognitive terms therefore risks rendering invisible precisely the forms of ecoliteracy that young children do display.

International reviews document both the growth and the persistent limits of research in this area. Early syntheses found that studies in early childhood education for sustainability were dominated by teacher perspectives and by descriptions of institutional routines rather than by evidence of children's own learning (Hedefalk et al., 2015; Somerville & Williams, 2015). More recent reviews report a larger and more varied evidence base, yet still identify weaknesses in outcome measurement and in the theorization of children's agency (Ardoin & Bowers, 2020; Yýldýz et al., 2021). Reviews focused on particular pedagogical traditions reach comparable conclusions, noting that studies seldom examine children's action-oriented engagement with sustainability and seldom make their conceptual commitments explicit (Rodrigues-Silva & Alsina, 2023). Where program design has been compared directly, children enrolled in ecologically oriented preschool programs have been found to have greater knowledge of sustainability topics than peers in programs with another emphasis, suggesting that what a setting provides matters as much as exposure to nature itself (Poje et al., 2024). A further pattern cuts across these syntheses. The evidence base is geographically skewed: a recent Scopus-based review of environmental education for young children found publication activity concentrated in high-income countries, with limited representation of research from the Global South (Mutiarasari et al., 2025). A broader review of environmental education teaching practices reaches the same conclusion and identifies the Global South as among the least represented regions in the literature (Zhang et al., 2025). What is known about ecoliteracy in early childhood is therefore largely what is known about it in a small number of national settings.

Indonesia illustrates what that imbalance conceals. National policy has moved towards

embedding sustainability in schooling, and recent work documents how educators translate education for sustainable development into pedagogical practice within the Kurikulum Merdeka in Indonesian early childhood centers (Pratiwi et al., 2025). Empirical studies have also accumulated. Environment-based education in coastal preschools has been reported to strengthen children's eco-literacy and naturalistic intelligence across knowledge, skills, values, and attitudes (Setyaningsih et al., 2024), and digital media have been proposed as a way to introduce eco-literacy to young learners (Ninsiana et al., 2024). Educator training has been shown to build teachers' commitment to environmental literacy (Chandrawati & Aisyah, 2022). Taken together, these studies signal an active field. Taken separately, they also expose a difficulty: eco-literacy, naturalistic intelligence and environmental literacy are frequently invoked as though interchangeable, and the dimensions and instruments attached to each vary from study to study. Much of this work, moreover, appears in nationally accredited journals or in education outlets rather than in the internationally indexed environmental science literature. A national field can therefore be active and yet remain almost invisible in the corpus from which international claims about early childhood ecoliteracy are drawn. The same is likely to hold for other settings outside the small group of countries that dominate the indexed literature. How far the indexed corpus actually extends is an empirical question that reviews of this construct have not yet asked.

Three gaps follow from this state of affairs. First, no systematic review has taken the ecoliteracy construct itself as its object. Existing syntheses address environmental education or education for sustainability broadly (Ardoin & Bowers, 2020; Mutiarasari et al., 2025; Yýldýz et al., 2021), so the conceptual work of specifying what ecoliteracy is, and how it differs from environmental literacy in the sense set out above, has not been carried out systematically for the early years. Without that boundary, a review cannot tell whether a study that measures environmental knowledge is evidence about ecoliteracy or about something narrower, and the mapping of the field remains a mapping of labels rather than of constructs. Second, because the construct is used inconsistently, it is not presently possible to state how ecoliteracy is defined, dimensioned, or assessed in this literature, which limits both the comparability of findings and the principled design of new instruments. Third, the geographical composition of the indexed corpus on this construct has not been documented, so it is unclear which national settings the available account of early childhood ecoliteracy rests on. Closing these gaps matters practically as well as conceptually, because teacher educators, curriculum developers and researchers all require a defensible account of what ecoliteracy means before it can be taught deliberately or assessed fairly.

This study therefore systematically reviews Scopus-indexed research on ecoliteracy in early childhood education published between 2016 and 2026 to establish how the construct is defined, taught, and assessed, and to map the resulting evidence base. Accordingly, this study is guided by four research questions:

RQ1. How is ecoliteracy defined and dimensioned in research on early childhood education?

RQ2. What learning strategies, media, and settings are most frequently used to foster ecoliteracy in young children?

RQ3. How is children's ecoliteracy assessed in this body of research?

RQ4. What research trends and gaps are apparent across the corpus, including its geographical distribution, and what directions do they suggest for future work?

By answering these four questions, the review contributes a consolidated account of a construct that is widely used but unevenly specified. It offers a dimensional framework that subsequent studies, including those conducted in settings currently absent from the indexed corpus, may adopt or contest rather than reconstruct from the beginning.

METHOD

This study employed a systematic literature review as its research design in order to produce a comprehensive synthesis of research on ecoliteracy in early childhood education. A systematic review was chosen because research in this field is dispersed across education, environmental science, and psychology and therefore requires a structured, transparent procedure to consolidate what is known (Snyder, 2019). The review was conducted and reported in accordance with the PRISMA 2020 statement (Page et al., 2021), which provides a rigorous framework for identifying, screening, and selecting studies reproducibly. The design also allows the four research questions to be addressed in sequence, moving from mapping definitions and dimensions, through pedagogical strategies and assessment practices, to identifying trends and gaps.

Data Sources and Search Strategy

The data for this review were drawn exclusively from the Scopus database. Scopus was selected because it indexes journals across education, psychology, and environmental studies under a consistent selection standard, and because its structured metadata for publication year, subject area, document type, and author keywords can be applied as reproducible filters and exported without loss. Comparative assessments of the major bibliographic databases describe Scopus as one of the two most comprehensive and reliable sources for this purpose (Pranckutë, 2021). The same database served as the sole source in a recent review of environmental education for young children (Mutiarasari et al., 2025), allowing the present findings to be read alongside that review rather than in isolation. Other databases such as Web of Science, ERIC and Google Scholar were considered but not used, and the consequences of this decision are addressed in the limitations of this article.

The search covered publications between 2016 and 2026, a window that begins in the year following the adoption of the Sustainable Development Goals and therefore captures the period in which Target 4.7 became an explicit reference point for early childhood policy and practice. The search strategy combined two concept blocks with the Boolean operator AND. The first block covered the construct family outlined in the introduction, in which ecoliteracy, ecological literacy, and environmental literacy circulate as near synonyms alongside adjacent terms for environmental and sustainability education (McBride et al., 2013). The second block covered the early childhood population. Truncation was used to capture morphological variants, and quotation marks were used to preserve phrase order. The complete strategy, with the query added at each step and the number of records it returned, is presented in Table 1. A review protocol setting out the research questions, concept blocks, eligibility criteria and extraction fields was drafted before the search, but it was not registered in a public registry such as PROSPERO, INPLASY or the Open Science Framework. One amendment was made during the review: we replaced the national databases named in the draft protocol with a single Scopus search, for the reasons given above. Both points are reported in line with item 24 of PRISMA 2020 (Page et al., 2021). No study registers were searched, which is why the register count in the identification box of Figure 1 is zero.

Table 1. Data sources and search strategy

Component	Description	Records retained
Database	Scopus	
Search field	Title, abstract and author keywords (TITLE-ABS-KEY)	
Date of data retrieval	9 September 2026	
Keywords	Construct block: ecoliteracy; "eco literacy"; "eco-literacy"; "ecological literacy"; "environmental literacy"; "environmental awareness"; "environmental knowledge"; "environmental education"; "environmental learning"; "sustainability education"; "education for sustainability"; "education for sustainable development"; "sustainable development education"; "sustainability learning"; "sustainability literacy"; "sustainable literacy"; "ecological education"; "ecology education". Population block: "early childhood"; "early childhood education"; preschool*; pre-school*; kindergarten*; "early years"; "young children"; "young child"; "preschool children"; "preprimary education"; "pre-primary education"; "early learners".	
Step 1. Concept blocks	(TITLE-ABS-KEY (ecoliteracy OR "eco literacy" OR "eco-literacy" OR "ecological literacy" OR "environmental literacy" OR "environmental awareness" OR "environmental knowledge" OR "environmental education" OR "environmental learning" OR "sustainability education" OR "education for sustainability" OR "education for sustainable development" OR "sustainable development education" OR "sustainability learning" OR "sustainability literacy" OR "sustainable literacy" OR "ecological education" OR "ecology education") AND TITLE-ABS-KEY ("early childhood" OR "early childhood education" OR preschool* OR pre-school* OR kindergarten* OR "early years" OR "young children" OR "young child" OR "preschool children" OR "preprimary education" OR "pre-primary education" OR "early learners"))	1.208
Step 2. Publication year	AND PUBYEAR > 2015 AND PUBYEAR < 2027	934
Step 3. Subject area	AND (LIMIT-TO (SUBJAREA , "ENVI"))	237
Step 4. Document type	AND (EXCLUDE (DOCTYPE , "ch") OR EXCLUDE (DOCTYPE , "cp") OR EXCLUDE (DOCTYPE , "re") OR EXCLUDE (DOCTYPE , "er") OR EXCLUDE (DOCTYPE , "bk") OR EXCLUDE (DOCTYPE , "ed") OR EXCLUDE (DOCTYPE , "tb") OR EXCLUDE (DOCTYPE , "sh") OR EXCLUDE (DOCTYPE , "no") OR EXCLUDE (DOCTYPE , "le") OR EXCLUDE (DOCTYPE , "cr"))	144
Step 5. Keyword facet	AND (LIMIT-TO (EXACTKEYWORD , "Early Childhood Education") OR LIMIT-TO (EXACTKEYWORD , "Environmental Consciousness") OR LIMIT-TO (EXACTKEYWORD , "Early Childhood Environmental Education"))	31

Retrieval and eligibility (full-text reading)	Seven reports without obtainable full text were moved to not retrieved; two reports addressing non-environmental sustainability were removed on reading	22

Inclusion and Exclusion Criteria

To ensure transparency and reproducibility, inclusion and exclusion criteria were established before screening began. The criteria were designed to focus specifically on ecoliteracy and its cognate constructs within early childhood settings, and are summarised in Table 2.

One criterion requires explanation because it defines the corpus's topical boundary. The two concept blocks search title, abstract, and author keywords, so a record qualifies when the terms appear anywhere in that text, including in passing. To restrict the corpus to studies for which early childhood and the environmental construct are the declared subject rather than an incidental mention, the Scopus keyword facet (EXACTKEYWORD) was applied as a final limit, retaining records indexed under Early Childhood Education, Early Childhood Environmental Education or Environmental Consciousness. Keyword indexing reflects editorial judgment about a study's topic, so using it as a limit increases topical precision at the cost of recall. Because this limit could exclude studies indexed under the ecoliteracy family of terms but not under any of the three keywords, we checked its effect on the first research question separately, as reported in the study selection process below. No geographical limit was applied at any stage; country of affiliation was recorded during extraction as a descriptive variable rather than used as a filter, so the geographical composition of the corpus is a finding of the review and not a property imposed on it.

Table 2. Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Publication type	Peer-reviewed journal articles indexed in Scopus.	Book chapters, conference papers, reviews, books, editorials, errata, notes, letters, short surveys, conference reviews, and retracted records
Time period	Published between 2016 and 2026	Published outside the specified window
Subject area	Indexed by Scopus under Environmental Science	Indexed exclusively under other subject areas
Keyword indexing	Records indexed by Scopus under at least one of the author keywords Early Childhood Education, Early Childhood Environmental Education or Environmental Consciousness.	Records indexed under none of these author keywords
Topic relevance	Articles that explicitly address ecoliteracy or a cognate construct in an early childhood context	Studies that mention environmental issues only in passing, or in which early childhood is not the focus
Study type	Empirical studies, whether qualitative, quantitative, mixed methods, action research, or development research, and conceptual studies directly related to the research questions	Opinion pieces, book reviews, and works without an empirical or conceptual basis
Language	Written in Indonesian or English	Written in another language

Study Selection Process

The selection process followed the four stages of the PRISMA 2020 flow, namely identification, removal of records before screening, screening, and eligibility assessment leading to inclusion. The resulting flow, with the number of records at each stage, is presented in Figure 1.

The search was run in Scopus on 9 September 2026 in five cumulative steps, each reproduced in Table 1 with the query component added and the number of records it returned, so every count in Figure 1 can be replicated. In step 1, the two concept blocks, combined across title, abstract, and author keywords, identified 1,208 records. Because a single database was searched, no duplicate records required removal. In step 2, the publication year limit removed 274 records automatically before screening, leaving 934 records to be screened. In step 3, the subject area limit removed a further 697 records that Scopus does not index under Environmental Science, leaving 237 records sought for retrieval.

The subject area limit requires justification, because much early childhood research in Scopus is indexed under Social Sciences or Psychology. Scopus assigns subject areas to journals rather than to articles, and a journal may carry several. The limit was chosen because this review concerns a construct with ecological content, and the Environmental Science category retains the journals in which ecological and educational concerns meet; many of these are co-indexed under Social Sciences as well, as the 15 included studies from Sustainability and the eight from the Australian Journal of Environmental Education and the Journal of Environmental Education show. The cost of the decision is that studies published in journals indexed only under Social Sciences or Psychology cannot enter the corpus. The findings are therefore interpreted throughout as describing how the construct is treated in the Environmental Science literature rather than in early childhood education as a whole, and the consequences of this boundary for the geographical findings are examined in the discussion and the limitations.

Of the 237 records sought, 100 reports could not be retrieved for review. Ninety-three of these are not journal articles because Scopus classifies them under another document type (step 4), namely book chapters (n = 50), conference papers (n = 20), reviews (n = 10), errata (n = 3), books (n = 3), editorials (n = 2), retracted records (n = 1), short surveys (n = 1), notes (n = 1), letters (n = 1), and conference reviews (n = 1). The remaining seven are journal articles whose full text could not be obtained through institutional subscriptions or open-access sources. In line with PRISMA 2020, these seven are reported as not retrieved and were not used in any part of the extraction, appraisal, or synthesis, even where an abstract was available. The remaining 137 reports were assessed for eligibility, and 115 were excluded for two reasons. One hundred and thirteen were excluded in step 5 because Scopus did not index them under any of the three keywords by which the topical boundary was drawn, which indicates that early childhood and the environmental construct were not the declared subject of the report. Two further reports were excluded on reading because the sustainability they address is not environmental: one concerns the sustainability and equity of the early childhood education system and the other the sustainability of teachers' caring. Twenty-two studies, all read in full text, satisfied all criteria and were carried into the synthesis, and all 22 are published in English.

The effect of the keyword facet on the first research question was checked directly. The 144 records retained after step 4 were exported from Scopus on 17 October 2026; the rerun returned the same 144 records, of which 31 satisfied step 5. Their titles, abstracts, author keywords, and indexed keywords were searched for ecoliteracy, eco-literacy, eco literacy, ecological literacy, and environmental literacy. None of the 144 records

contain ecoliteracy, eco-literacy, eco literacy, or ecological literacy. Four contain environmental literacy, and all four were removed in step 5 because they are not indexed under any of the three keywords (Arif et al., 2025; López-Alcarria et al2021; Lu et al., 2024; Restoviæ et al., 2026).

Screening and eligibility decisions were recorded in a spreadsheet by the first author and were verified independently by the second and third authors on a sample of records, with disagreements resolved through discussion rather than by majority vote.

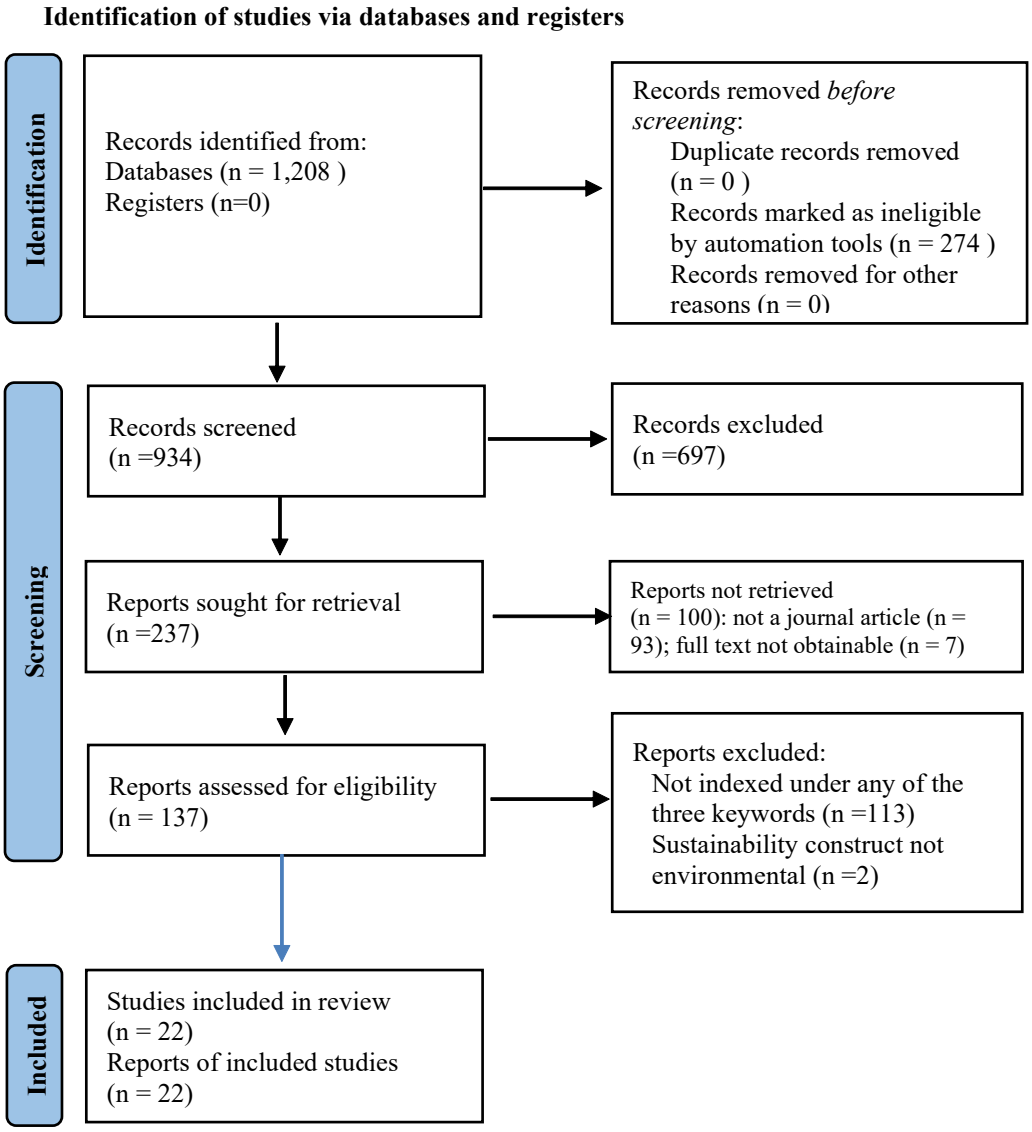


Figure 1. PRISMA 2020 flow diagram of the study selection process

Data Extraction and Analysis

Data were extracted into a matrix designed to answer the four research questions. For each included study, the matrix recorded the bibliographic details, the country and region of author affiliation and of the study setting, the type of setting, the age range and number of children, the research design and data collection technique, the exact term used for the construct, the theoretical source cited for it, the dimensions and

indicators employed, the learning strategy or intervention described, the method used to assess children's ecoliteracy, and the main findings together with the limitations acknowledged by the authors. All entries were taken from the full text of each study. Extraction was assisted by a large language model (Claude, Anthropic), which was given the full text and the extraction fields for one study at a time; every entry was then checked against the source text by the first author, and the coding of construct terms and dimensions was discussed with the second and third authors. For reporting, these fields were condensed into a synthesis matrix (Table 3) that groups studies by research theme and provides, for each study, its research focus, key finding, the dimensions observed, the assessment of children, and the instrument used and its appraisal result. The three themes were derived from the learning strategies coded for the second research question.

The methodological quality of the included studies was appraised using the Mixed Methods Appraisal Tool (MMAT) version 2018 (Hong et al., 2018), which was selected because it accommodates quantitative, qualitative and mixed methods designs within a single framework. Each empirical study was rated as yes, no, or cannot tell against the five criteria of its design category and, as the MMAT guidance recommends, the result is reported as the number of criteria met rather than as an overall score. Preliminary ratings were prepared with the same language model and then verified against the full text by the authors. The MMAT is not designed for conceptual papers or document analyses, so the two conceptual studies and the two policy analyses were not appraised. Studies were not excluded based on the appraisal, since the distribution of methodological quality is itself informative for the fourth research question.

Analysis combined descriptive mapping with thematic synthesis. Descriptive mapping summarised the distribution of studies by year, country, publication outlet, setting, design and age group. Thematic synthesis followed the three-stage procedure described by Thomas and Harden (2008), in which the findings sections of the included studies were coded line by line, the codes were organized into descriptive themes, and analytical themes were then generated to answer the review questions. The dimensions reported in each study were also mapped onto the head, hands and heart framework (Sipos et al., 2008) to determine whether the included studies employ an ethical or restraint-oriented dimension alongside the cognitive, affective and behavioral domains. Each domain was coded as stated explicitly, present but marginal, not stated, or not mappable when a study rejects dimensioning as a way of working.

Relations among the concepts were examined through a structured qualitative thematic analysis rather than a bibliometric co-occurrence analysis, because a corpus of 22 documents is too small for term clustering to yield stable and meaningful clusters. We applied a codebook with four code families corresponding to the research questions (construct term, dimensions, learning strategy, and assessment of children) to the full text of every study in the extraction spreadsheet. The codes were then cross-tabulated across studies, for instance, learning strategy against assessment approach, to identify which themes occur together and which do not. These relations are reported in the discussion of the fourth research question and summarised in Figure 4. The counts of publication year, country of affiliation and source title reported in the results were computed from the Scopus export of the included records.

RESULT AND DISCUSSION

This section reports the findings for the 22 included articles. It begins with the corpus characteristics and then addresses each of the four research questions in turn, moving from how

the construct is specified, through learning strategies and assessment practices, to the trends and gaps that emerge across the corpus.

Characteristics of the Included Studies

The 22 studies were published between 2019 and 2026. Five appeared in the first half of the search window, from 2016 to 2020, and 17 in the second half, from 2021 to 2026, with four studies in each of 2021, 2024 and 2025. Their distribution across outlets is uneven. Fifteen studies appeared in Sustainability, five in the Australian Journal of Environmental Education, and one each in the International Electronic Journal of Environmental Education and WSEAS Transactions on Environment and Development. More than two-thirds of the corpus therefore comes from a single open-access megajournal, and almost a quarter from a single regional journal. The distribution by year of publication and by source title is presented in Figure 2.

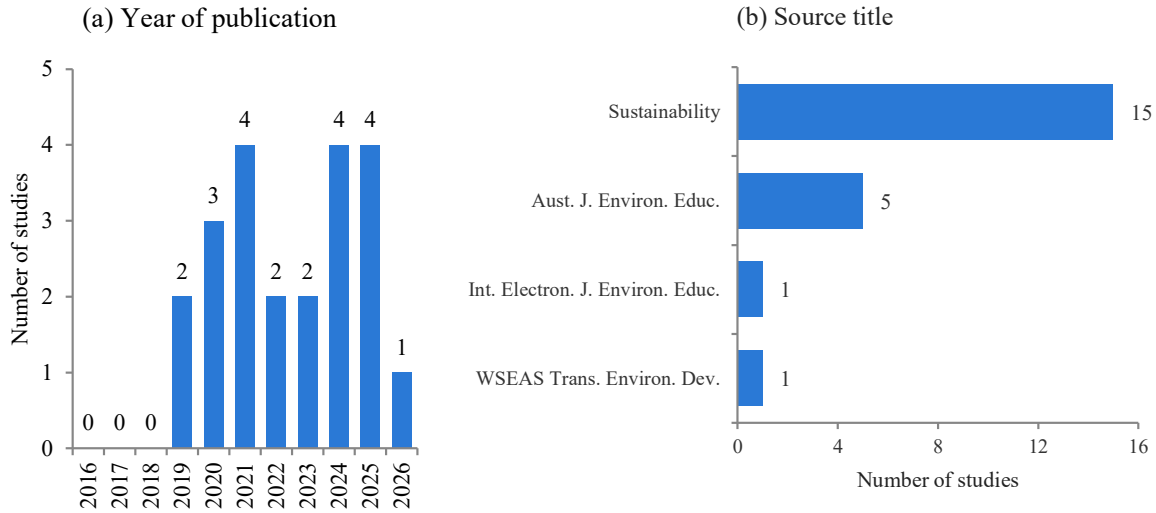


Figure 2. Distribution of the 22 studies by year of publication and by source title

Author affiliations span 15 countries. Australia contributes six studies, followed by Turkey and Norway, each with four. Canada, Germany, and the United States contribute two each, and nine other countries, including China and Vietnam, contribute one each. None of the 22 studies is affiliated with an institution in Indonesia, and none uses Indonesia as its research setting. Southeast Asia is represented by a single study from Vietnam (Yen et al., 2023), and South Asia is n represented. No geographical limit was applied at any stage, so this absence is not the result of a country filter; the discussion examines whether it reflects the subject area and keyword limits. The full distribution of countries of affiliation is presented in Figure 3.

Qualitative approaches dominate the research designs, accounting for 11 studies in the form of case studies, ethnographies, phenomenography, and grounded theory. Three studies are experimental or quasi-experimental, two are non-experimental quantitative, two use mixed methods, two are conceptual papers, and two analyze documents or policy. Children are participants in 14 studies. Four studies involve only teachers or pre-service teachers, one involves parents, two analyze policy documents, and one has no participants. Most studies with

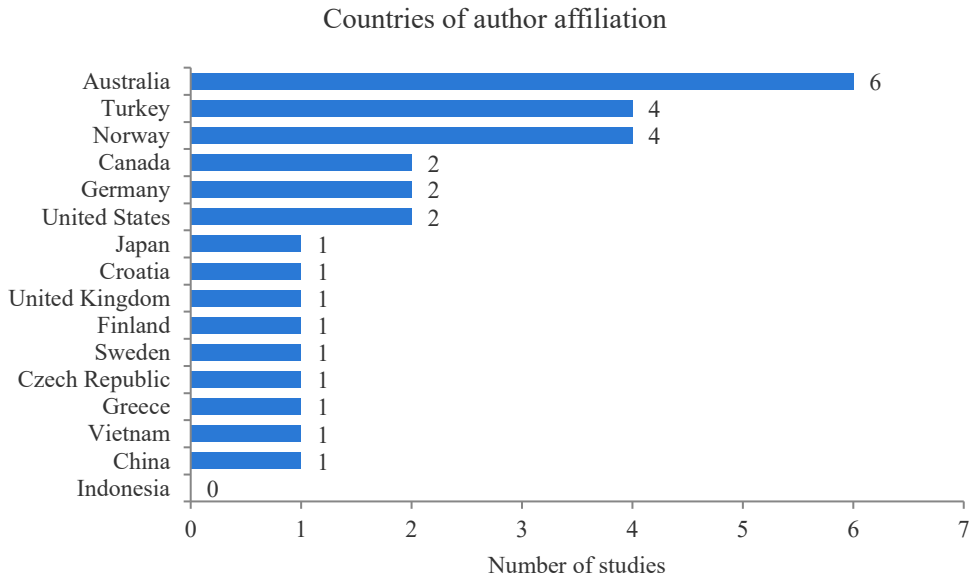


Figure 3. Countries of author affiliation across the 22 included studies

child participants report ages between three and six years. The 22 studies are presented in the synthesis matrix in Table 3, grouped into three research themes, with the research focus, key finding, dimensions observed, assessment of children, and appraisal result of each, and the research designs and participants are summarised in Table 4.

Table 3. Synthesis matrix of the 22 included studies grouped by research theme

No. Study (country)	Design; MMAT	Research focus	Key finding	Dimensions observed	Assessment of children
Theme 1. Nature-based outdoor learning (11 studies)					
1. Beasley et al. (2023), Australia	Qualitative; 4/5	Place-based botanical inquiry with two teachers over one year Term: botanical literacies	Teachers moved from limited native-plant knowledge to confident botanical inquiry; an Elder visit was the most valued element.	Head; Hands; Heart (marginal: ethical)	Not assessed
2. Beattie et al. (2025), Canada	Qualitative; 5/5	Grade 1 children (5 to 7 years) and sticks in a forest site, through Wild Pedagogies and the Mosaic approach Term: early childhood environmental education	Children used sticks physically and symbolically; place and natural objects acted as co-teachers and fostered care.	Hands; Heart; Ethical (marginal: head)	Qualitative description (child-worn video, conversations)
3. Kahriman-Pamuk (2020), Turkey	Qualitative; 4/5	Perceptions of 39 parents of forest preschool children Term: environmental awareness	Parents linked the forest preschool to positive emotions, nature discovery, and growth in environmental awareness.	Head; Hands; Heart (marginal: ethical)	Not assessed (parents' reports)
4. Wolff and Skarstein (2020), Finland and Norway	Mixed methods; 4/5	Species learning in early childhood teacher education Term: species knowledge	Correct species identification rose from 66% to 90%; students linked species knowledge to teaching and sustainability.	Head; Hands; Heart; Ethical	Not assessed (student teachers)
5. Beery and Magntorn (2021), Sweden	Quasi-experimental; 1/5	Pre-service educators' excursion to a UNESCO biosphere reserve Term: early childhood environmental education	Self-rated understanding of biosphere and ecosystem concepts rose; response fell to 32% at delayed post-test	Head; Heart (marginal: hands, ethical)	Not assessed (self-report survey)

6. Ernst and Burcak (2019), United States and Turkey	Quasi-experimental; 2/5	Nature preschools compared with non-nature preschools (3 to 5 years) Term: early childhood environmental education	Nature-preschool children gained more in creative thinking and resilience; no difference in executive function.	Head (developmental outcomes, not environmental understanding)	Standardized scores (MEFS, TCAM, DECA-P2, curiosity box)
7. Wintoneak (2025), Australia	Qualitative; 4/5	Year-long walking-with-river project with children aged 2 to 5 Term: environmental education	Audiowalking and micromapping unsettled nature and culture binaries in research practice	Head, hands and heart not mappable; ethical stated	Not assessed
8. Bergan et al. (2021), Norway	Qualitative; 4/5	Foraging and gardening projects as communities of practice Term: education for sustainability	Children and staff learned together through authentic outdoor food practices tied to local heritage.	Head; Hands; Heart (marginal: ethical, restraint)	Qualitative description (staff focus groups, video)
9. Speldewinde and Campbell (2026), Australia	Qualitative; 4/5	Beach kindergarten sessions in coastal blue spaces Term: education for sustainability	Educators kept technology from children's play while using devices to support their own sustainability pedagogy.	Head; Hands (marginal: heart, ethical, restraint)	Qualitative description
10. Speldewinde and Campbell (2024), Australia	Qualitative; 5/5	Bush kinders at four sites Term: environmental education	Educator scaffolding at the point of need fostered knowledge, sensitivity, and concern for nature.	Head; Hands; Heart (marginal: ethical)	Qualitative description
11. Audley et al. (2024), United States and Canada	Qualitative; 5/5	Moral reasoning in nature-based programs (19 educators) Term: early childhood education for sustainability	Educators seldom engaged children in moral reasoning; harm reduction was the principle most often addressed	Hands; Ethical (marginal: head, heart, restraint)	Not assessed
Theme 2. Technology, story media and structured programs (6 studies)					
12. Şimşek (2024), Turkey	Quasi-experimental; 4/5	Augmented reality compared with coloring pages for life cycles (94 children, 48 to 60 months) Term: environmental education	The augmented reality group scored higher at post-test (d = 1.68)	Head (marginal: hands)	Rubric (Life Cycle Test, nine open items scored 0 to 2)
13. Feriver et al. (2019), Turkey and Germany	Qualitative; 5/5	Systems thinking after a picture book (52 children, 4 to 6 years) Term: systems thinking	Children detected gradual change and two-step causality but seldom feedback loops or hidden components.	Head (marginal: ethical)	Rubric (Systems Thinking Developmental Rubric, eight aspects)
14. Poje et al. (2024), Croatia	Quantitative comparative; 1/5	Ecological compared with language kindergarten program (58 children, 5 to 6 years) Term: environmental education	Children in the ecological program scored higher on a 12-item knowledge test.	Head; Hands; Heart (marginal: ethical, restraint)	Scored measure (17-item questionnaire, not validated)
15. Kanaki et al. (2025), Greece	Qualitative; 5/5	Bee-Bot programming with water cycle content (44 pupils) Term: environmental awareness	Pupils preferred programming and collaboration; drawings showed awareness of the benefits and hazards of water.	Head; Hands; Restraint (marginal: heart)	Qualitative description
16. Carrizo et al. (2025), Australia	Conceptual; NA	Indoor sensory exploration of dust under a microscope Term: environmental education	Argues for rewilding early childhood pedagogies through children's encounters with microworlds	Head, hands and heart not mappable; ethical stated	Qualitative description
17. Yen et al. (2023), Vietnam	Mixed methods; 3/5	Fun activities and sustainable environmental behavior (300 teachers, 156 children) Term: sustainable environmental behavior	Activity content, game rules and specific protective actions emerged as factors shaping behavior.	Head; Hands; Heart	Qualitative description (observation)

Theme 3. Studies without an intervention: conceptions, practices, policy and theory (5 studies)					
18. Jančaříková (2021), Czech Republic	Qualitative; 4/5	Answers of 302 children to the question "What is nature?" Term: children's conceptions of nature	Most children defined nature as a list of living things and expressed utilitarian to moralistic values.	Head; Heart; Ethical (marginal: hands)	Qualitative description
19. Cheng and Yu (2022), China	Quantitative descriptive; 4/5	Education for sustainable development practices of 7,287 educators Term: education for sustainable development	High self-rated practice overall (M = 4.27 of 5), highest for values and lowest for content	Head; Hands; Heart; Ethical	Not assessed (self-report scale)
20. Sadownik and Gabi (2021), Norway and United Kingdom	Conceptual; NA	Posthuman theorization of belonging Term: sustainability's holism	Belonging emerges from human-nonhuman entanglement, reconnecting the pillars of sustainability.	Heart; Ethical (marginal: head, hands)	Not assessed
21. Holst et al. (2020), Germany	Policy analysis; NA	Education for sustainable development in German early childhood documents Term: education for sustainable development	Present in 9 of 16 state education plans and absent from laws	None stated explicitly (marginal: head, hands, ethical)	Not assessed
22. Almeida et al. (2022), Australia and co-authors abroad	Policy analysis; NA	Environmental and sustainability education in curricula of India, China and Japan Term: environmental and sustainability education	Sustainability is not named, and nature is framed as a learning resource	Head; Hands; Heart; Ethical	Not assessed

MMAT = number of the five MMAT criteria met; NA = not appraised (conceptual or policy study). Dimensions observed follow the coding in Table 5.

Table 4. Research designs and participants across the 22 included studies

Aspect	Category	Number of Studies
Design	Qualitative	11
	Experimental or quasi-experimental	3
	Non-experimental quantitative	2
	Mixed methods	2
	Conceptual	2
	Document or policy analysis	2
Participants	Young children	14
	Teachers or pre-service teachers only	4
	Parents	1
	Documents or policy	2
	No participants	1

Methodological Quality of the Included Studies

We could appraise 18 of the 22 studies with the MMAT. Five met all five criteria, nine met four, one met three, one met two, and two met one (Table 3). The pattern follows design. The qualitative studies met most criteria, and their most frequent shortfall was data collection confined to a few participants or a single site. The non-randomized quantitative studies fared worst, because confounders were seldom accounted for and samples were drawn by convenience. Both studies that produce numerical scores for children are among the weakest: one relies on an unvalidated knowledge test (Poje et al., 2024), and the other on developmental measures not directed at environmental understanding (Ernst & Burcak, 2019). The evidence on what children learn is therefore thinnest exactly where it is quantified.

RQ1. Terminology, Theoretical Sources and Dimensions of the Construct

The most striking finding for the first research question is negative. None of the 22 studies use ecoliteracy, eco-literacy, or ecological literacy as their principal construct term, and none of the titles, abstracts, or keywords include ecoliteracy, ecological literacy, or environmental literacy. Within the full texts, ecological literacy appears only once, as a subsidiary term alongside species knowledge and sustainability education (Wolff & Skarstein, 2020). This absence is not produced by the keyword facet in step 5. Because the ecoliteracy family of terms was part of the step 1 query, any Environmental Science article that used these terms together with an early childhood term would have been among the 144 records retained after step 4, and none of those records use ecoliteracy, eco-literacy, or ecological literacy. The keyword facet did, however, remove the four records that use environmental literacy, so the finding for that term holds only for the corpus. Twelve different principal terms are used across the 22 studies. Environmental education is the most frequent (five studies), followed by early childhood environmental education (three), education for sustainability, including early childhood education for sustainability (three), education for sustainable development (two), and environmental awareness (two); each of the remaining seven studies uses a term of its own, from botanical literacies to sustainable environmental behavior. The principal term of each study is shown in the research focus column of Table 3.

The theoretical sources cited to define the construct are diverse and seldom shared. Some studies anchor the construct in named frameworks, such as communities of practice (Bergan et al., 2021), the in, about and for the environment formulation of early childhood education for sustainability together with social domain theory (Audley et al., 2024), Wild Pedagogies and the Mosaic approach (Beattie et al., 2025), or posthuman and agential realist thought (Sadownik & Gabi, 2021; Wintoneak, 2025). Others take their definition from policy texts, either by design, as in the analyses of national curriculum documents (Almeida et al., 2022; Holst et al., 2020), or by adopting an official definition of environmental education, as in the use of the definition of the United States Environmental Protection Agency in the study of bush kinders (Speldewinde & Campbell, 2024). Few studies share a framework.

Twenty studies state the dimensions or components of their construct, while two state none (Carrizo et al., 2025; Wintoneak, 2025). Both are posthuman studies that expressly reject dimensioning as a way of working. Mapping the stated dimensions onto the head, hands and heart framework (Sipos et al., 2008) reveals an uneven pattern, presented in Table 5. The cognitive domain is stated explicitly in 16 studies and the affective domain in 13. In comparison, the action domain is stated explicitly in 13 studies and appears in a further six only as activities children undertake rather than as a specified capability. The ethical dimension is stated explicitly in nine studies, appears only marginally in nine, and is not stated in four. A restraint dimension, meaning a willingness to take and consume less, is almost absent. Only one study states it explicitly, through water conservation practices (Kanaki et al., 2025); four touch on it marginally, and 17 studies do not state it at all.

Table 5. Mapping of stated dimensions onto the head, hands and heart framework

Domain	Stated Explicitly	Present But Marginal	Not Stated	Not Mappable
Head (cognitive)	16	4	0	2
Hands (action)	13	6	1	2
Heart (affective)	13	4	3	2
Ethical dimension	9	9	4	0
Restraint dimension	1	4	17	0

RQ2. Learning Strategies, Media and Settings

The settings and strategies investigated focus on a single type. Eleven studies examine nature-based outdoor learning, which appears in several forms: bush kinders in Australia (Speldewinde & Campbell, 2024), a forest preschool in Turkey (Kahriman-Pamuk, 2020), nature play in the United States (Ernst & Burcak, 2019), place-based botanical learning in Western Australia (Beasley et al., 2023), Wild Pedagogies combined with the Mosaic approach in Canada (Beattie et al., 2025), foraging and gardening projects in Norway (Bergan et al., 2021), walking with a river in Western Australia (Wintoneak, 2025), and learning in coastal blue spaces (Speldewinde & Campbell, 2026). Two studies examine digital technology: augmented reality for teaching life cycles ([a]im[o]ek, 2024) and a Bee-Bot floor robot that combines algorithmic thinking with environmental awareness (Kanaki et al., 2025). The remainder are single instances: a structured kindergarten ecology program (Poje et al., 2024), a picture book as a stimulus for systems thinking (Feriver et al., 2019), environmentally themed role play (Yen et al., 2023), and indoor sensory exploration of dust under a microscope (Carrizo et al., 2025).

Five studies examine no particular learning strategy. This group comprises two policy analyses, a conceptual essay, a study of children's conceptions of nature and a survey of educators' practices, none of which takes an intervention as its object, such as the analysis of how education for sustainable development is anchored in the formal documents of the German education system (Holst et al., 2020). Nearly a quarter of the corpus therefore offers no evidence about how the construct it discusses might be cultivated.

RQ3. How Children Are Assessed

The third research question produces the sharpest finding. Ten of the 22 studies, nearly half, do not assess children at all. Five of these assess teachers or pre-service teachers, two analyze policy documents, one examines parents' perceptions, one has no empirical data, and one examines children's relations with a river without assessing their understanding. Beery and Magntorn (2021), for instance, measure pre-service educators' self-perception after an excursion to a biosphere reserve, while Cheng and Yu (2022) measure educators' practices through a self-report scale without touching children's outcomes. Eight studies assess children through qualitative description of their talk, drawings, and play, without scores or rubrics, as in the mapping of Czech children's conceptions about nature (Janèaøíková, 2021). Only four studies use an instrument that yields a number or a level: two use scored measures (Ernst & Burcak, 2019; Poje et al., 2024) and two use rubrics (Feriver et al., 2019; [a]im[o]ek, 2024). The assessment approach and instrument of each study are given in the last column of Table 3.

Even these four instruments do not measure the same thing. [a]im[o]ek (2024) assesses understanding of life cycles through nine open questions scored from 0 to 2. Feriver et al. (2019) use a Systems Thinking Developmental Rubric with a four-point scale across eight aspects of systems thinking. Poje et al. (2024) use a 17-item questionnaire that separates knowledge from attitudes. Ernst and Burcak (2019) measure general developmental outcomes, namely curiosity, executive function, creative thinking, and resilience, rather than environmental understanding itself. No instrument is used by more than one study.

RQ4. Research Trends and Gaps

Four trends emerge across the corpus. First, publication activity has grown, from five studies in 2016 to 2020 to 17 studies in 2021 to 2026, and the more recent studies include relational and posthuman approaches that situate

children within entanglements with the more-than-human (Sadownik & Gabi, 2021; Carrizo et al., 2025; Wintoneak, 2025).

Second, the corpus is geographically concentrated: three countries contribute 14 of the 22 studies, while Africa, Latin America, and South Asia are not represented at all, and Indonesia is absent within the boundaries of this search. Third, the construct at the center of this review circulates without a stable name. No study takes ecoliteracy as its principal term, and twelve different principal terms are in use. Fourth, nearly half the corpus does not assess children, so claims about what children learn rest largely on adults' accounts and researchers' interpretations of children's behavior.

The structured thematic analysis shows how these patterns relate. When learning strategy is cross-tabulated against assessment of children, the six studies of technology, story media, and structured programs all assess children: three with a scored measure or a rubric and three through qualitative description. In contrast, six of the eleven nature-based studies do not assess children at all, and only one uses a scored measure. The setting that dominates the corpus is therefore also the one in which children's learning is least often examined. Of the five studies that touch on restraint, explicitly or marginally, three are nature-based, one is a structured program, and one uses digital technology (Table 3), so restraint is not tied to any single type of setting; it appears where a study happens to involve water, food or waste, rather than as a planned aim.

The same cross-tabulation also locates the affective domain. All but one of the nature-based studies state or touch on the affective domain, whereas two of the six studies in the second theme, both focused on conceptual understanding, do not state it (Feriver et al., 2019; ªimºek, 2024). The relations among construct naming, dimensions, strategies and assessment are summarised in Figure 4.

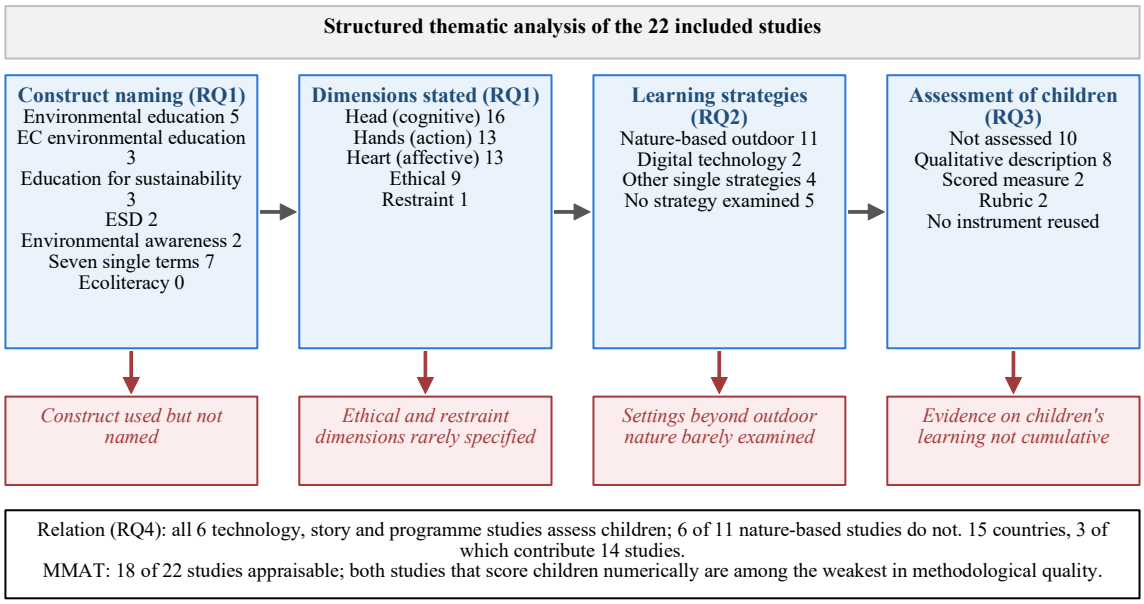


Figure 4. Relations among construct naming, dimensions, learning strategies and assessment identified through the structured thematic analysis of the 22 included studies

This absence has a practical consequence. A search on ecoliteracy or ecological literacy would retrieve none of the 22 studies, and none of the 144 Environmental Science articles from which they were drawn, although every one of them addresses the same problem, so the retrieval difficulty described by McBride et al. (2013) still holds for this part of the early childhood literature. Environmental literacy is the only term of the family that appears at all, in four articles outside the corpus, where it mostly names a broader aim than the study's own construct, for instance, the digital and environmental literacy fostered through structured storytelling with preschoolers (Lu et al., 2024) or a model of the action competencies teachers need to manage an eco-school (López-Alcarria et al., 2021). The finding should nonetheless be read within the subject-area boundary. This search cannot establish whether early childhood journals indexed only under Social Sciences or Psychology use the term ecoliteracy.

A Construct Used but Not Named

The absence of the term ecoliteracy from this corpus both confirms and extends McBride et al.'s (2013) warning about terminological drift. This review finds not merely that several terms circulate as synonyms, but that a term used extensively in Indonesian-language scholarship is not the term under which these Scopus-indexed studies in Environmental Science are written and indexed. The difference is not merely lexical. Environmental education, the most frequent principal term, names a field and a practice, whereas ecoliteracy names a capability residing in the child. When a field names itself after a practice, what is easiest to research is what adults provide rather than what forms in children. That pattern is visible in the next finding.

For Indonesian researchers, the consequence is immediate. Using the term ecoliteracy means using a term that will find almost no match in the indexed literature, so literature searches remain incomplete and theoretical positioning becomes hard to compare. The response is not to abandon the term but to state its relationship to the terms in circulation, and to make explicit that it refers to a capability in the child rather than a program delivered to the child.

When Children Are Not Assessed

The finding that nearly half the corpus does not assess children echoes and updates the conclusions of Hedefalk et al. (2015) and Somerville and Williams (2015), who a decade ago reported that research in this area was dominated by teacher perspectives and descriptions of institutional routines. The evidence base has grown, but its underlying composition has not changed. Ardoin and Bowers (2020) and Yýldýz et al. (2021) identified weaknesses in outcome measurement; this review shows the concrete form of that weakness: only four of 22 studies use an instrument that yields a number or level, and no instrument is reused by another study.

It should be said plainly that the absence of scored assessment is not in itself a weakness. Young children express understanding through action, play and talk, so qualitative description of their talk and drawings, as eight studies in this corpus undertake, matches how children actually show what they know. The difficulty lies in the consequences for accumulating evidence. When each study specifies for itself what it is looking at, and no instrument is shared, findings cannot be added together. The field continues to produce studies without building cumulative knowledge.

The Thin Ethical and Missing Restraint Dimensions

Mapping onto the head, hands and heart framework shows that the three classical domains are reasonably well represented, but two dimensions decisive for sustainability are thinly

specified. The ethical dimension is stated explicitly in only nine studies. It is marginal in a further nine, and a restraint dimension is stated explicitly in only one study and not at all in 17. This means that a willingness to take less, to reuse, and to limit wanting, which is the core of sustainable conduct, is rarely specified as part of what children are meant to develop.

That absence aligns with Rodrigues-Silva and Alsina (2023), who note that studies seldom examine children's action-oriented engagement. It also aligns with Almeida et al. (2022), who find that nature is often positioned as a learning resource rather than as an entity deserving respect. Where nature is a resource, restraint makes no sense as a learning aim. The single study that states this dimension explicitly does so through highly concrete water conservation practices (Kanaki et al., 2025), and that concreteness demonstrates that restraint can be taught in the early years once it is specified as an aim. A similar indication appears in the moral reasoning of United States educators, who link sustainability to harm reduction through everyday practices such as the zero-waste lunch (Audley et al., 2024).

A Corpus Resting on Few Countries

The corpus's geographical composition deserves separate comment. Fifteen countries are represented, yet three of them, Australia, Turkey and Norway, account for 14 of the 22 studies. Africa, Latin America and South Asia are not represented at all, and a single study from Vietnam represents Southeast Asia (Yen et al., 2023). The available account of early childhood ecoliteracy within Environmental Science is therefore a small set of national settings, and the most populous regions are the least audible.

A country's absence from the corpus can mean two different things, and Indonesia is the clearest case to work through because the evidence is at hand. It may mean that research on early childhood ecoliteracy in that country is genuinely scarce, or it may mean that such research exists but does not reach the databases that serve as international reference points. For Indonesia, the available evidence supports the second reading. Research in Indonesia is active, ranging from environment-based education in coastal preschools (Setyaningsih et al., 2024) to educator training for environmental literacy (Chandrawati & Aisyah, 2022). Most of this work appears in nationally accredited journals and is therefore beyond the reach of a search in an international database. A comparable pattern is likely to hold for other countries absent from this corpus, although establishing it would require a country-by-country study.

The search boundary itself may also have contributed to this absence. No geographical limit was applied, but the subject and keyword limits were, and Indonesian work does appear in international journals. Research on education for sustainable development in Indonesian early childhood centers has been published in Environmental Education Research (Pratiwi et al., 2025), and a study on introducing eco-literacy to young learners through digital media has appeared in an international education journal (Ninsiana et al., 2024), yet neither entered this corpus. The subject area and keyword limits, and not only the volume of research produced in a country, therefore shape the geographical picture. Comparisons with reviews that used other boundaries suggest, however, that the imbalance is not an artifact of this search alone. The finding agrees with the pattern reported by Mutiarasari et al. (2025) and Zhang et al. (2025) concerning the concentration of publications in high-income countries and the thin representation of the Global South, and with Rodrigues-Silva and Alsina (2023), who searched four databases including the Latin American SciELO and retrieved 12 studies, of which four came from Australia, three from the United States and one from Chile. This review adds sharpness: for this construct within

Environmental Science, representation across several regions is not thin, but nil, and Indonesia is among them. The finding is therefore best read as a statement about the visibility of research in this part of the indexed literature, not as a measure of how much research each country produces. The consequence runs in both directions. The international field loses evidence from a tropical, archipelagic and densely populated setting whose environmental problems differ fundamentally from those of the settings that dominate the corpus. Conversely, researchers in those settings build frameworks and instruments without connecting to the conversation under way, so the same work is done repeatedly.

Implications

Three implications follow. For instrument development, the mapping in Table 5 can serve as a starting framework: an early childhood ecoliteracy instrument should span the cognitive, action, and affective domains. It should deliberately add the ethical and restraint dimensions that have been missing. Adding those two dimensions is not arbitrary, since both are central to what sustainable living means.

In practice, the focus on nature-based outdoor learning suggests that other settings remain largely unexamined. Only two studies investigate digital technology and only one investigates story media, although both are common in Indonesian early childhood settings. For research, Indonesia's absence from the corpus is an opportunity rather than merely a shortfall. Studies with an explicitly stated construct, a fully reported instrument, and an international indexed outlet would fill a real gap rather than add to an already crowded area.

Limitations

This review has four limitations that must be stated. First, only one database was searched. Scopus was chosen for its structured, reproducible metadata, but Web of Science, ERIC,, and national databases such as Garuda include work beyond the reach of this search. Second, the search was restricted to the Environmental Science subject area, which removed 697 records. Much early childhood education research is published in journals indexed under Social Sciences or Psychology, so this corpus describes how the construct is treated within the environmental science conversation rather than across early childhood education as a whole.

Third, the final refinement used the Scopus keyword facet. That filter raises topical precision but excludes articles that address the construct without being indexed under those three keywords. A check of the 144 records retained after step 4 showed that it removed no article using ecoliteracy, eco-literacy, or ecological literacy. However, it removed four articles using environmental literacy, three of which concern early childhood settings, so findings about that term apply only to the corpus. Fourth, seven journal articles whose full text could not be obtained were treated as not retrieved, so any evidence they contain is absent from the synthesis. These limitations bound the reach of the review, but they do not weaken its principal findings, because those findings are negative ones: what is reported is what is absent from the corpus that could be reached.

■ CONCLUSION

This systematic review of 22 Scopus-indexed articles in the Environmental Science subject area, all read in full text, shows that, within this corpus, the construct called ecoliteracy in parts of the early childhood literature circulates under twelve other principal names, chiefly environmental education, and not under the name ecoliteracy itself; the term does not appear in any of the 144 Environmental Science articles from which the corpus was drawn. Because the search

was bounded by subject area, this finding describes the Environmental Science literature and should not be generalized to all early childhood education publications. The construct is generally specified through cognitive, action, and affective domains, but seldom includes an ethical dimension and rarely a restraint dimension. The learning strategies investigated focus on nature-based outdoor learning, while story media and digital technology remain barely examined. Nearly half the corpus does not assess children at all; the four studies that use a scored instrument or a rubric use four different instruments, and the two studies that score children numerically are among the weakest in methodological quality.

The concentration of the corpus in a few countries, with Indonesia and most of the Global South not represented within this search boundary, is itself a finding with implications in both directions. Future research should state its construct and dimensions explicitly, develop and report instruments that other researchers can reuse, deliberately include the ethical and restraint dimensions, and direct its findings to internationally indexed outlets so that evidence from Indonesian settings can enter a conversation that has so far proceeded without it. Future reviews should extend the search to the Social Sciences and Psychology subject areas and to regional databases, to test whether the patterns reported here hold beyond the Environmental Science literature. They should also include the studies of environmental literacy that the keyword facet set aside, so that they can be compared with the corpus reported here.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used Claude (Anthropic) to assist with extracting data from the full texts of the included studies, as described in the Method section, to refine the language, and to check consistency between in-text citations and the reference list. The authors verified all extracted data and quality appraisals against the source documents, and the analysis, interpretation, and conclusions presented are the authors' own. After using this tool, the authors reviewed and revised the content as needed and take full responsibility for the final content of this article.

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