Review Article

EDUCATIONAL POINT
An International Peer-Reviewed Journal

https://www.educationalpoint.net
ISSN: 3062-1011 (Online)

# Systematic review of problem-based learning in environmental education

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**CITATION:** Biney, E. (2025). Systematic review of problem-based learning in environmental education. *Educational Point*, *2*(2), e131. https://doi.org/10.71176/edup/17292

**ARTICLE INFO**

Received: 26 Jul 2025
Accepted: 15 Sep 2025

**OPEN ACCESS**

**ABSTRACT**

This systematic literature review synthesizes existing research to explore the use of Problem-Based Learning (PBL) as an instructional pedagogy and its impacts on achieving the goals of Environmental Education (EE). A search across Google Scholar, ERIC, and EBSCO Host databases using the Boolean search term (“Problem-Based Learning” AND “Environmental Education”) yielded 12,986 results. After applying rigorous inclusion and exclusion criteria, 52 peer-reviewed, empirical studies published between 2005 and March 2025 were selected for analysis. Findings reveal a steady increase in PBL in EE research over the past two decades, with most studies conducted in Indonesia and Turkey. PBL was found to promote the goals of EE by enhancing students’ environmental literacy, critical thinking, collaboration, and problem-solving skills. Dominant research methodologies were experimental and quasi-experimental and research lines were predominantly intervention- outcome based (46%). While session durations varied, most studies used short- to medium-term interventions with nearly half of the studies neither specifying the duration nor describing their PBL process. Few studies tracked long-term behavioral impacts of PBL on EE goals on participants. Study participants were mostly middle school and college learners. Studies reported the integration of EE in a variety of subject areas, mostly environmental and general science content areas. Notable gaps include a lack of standardized reporting guidelines which limit reproducibility. To address this gap, a framework: PBL Implementation Reporting Protocol for Environmental Education Research is proposed. This review contributes to the discourse on active learning pedagogies in EE towards the achievement of EE goals and offers insights, research and practice recommendations for advancing equitable, context-sensitive PBL integration in EE practice across educational levels.

**Keywords:** problem-based learning, environmental education, systematic review

# INTRODUCTION

In an era defined by escalating environmental crises and devastating impacts of climate change on human populations and ecosystems, the need for effective Environmental Education (EE) has never been more urgent. However, achieving environmental literacy that translates into sustainable action requires more than just the impartation of knowledge; it necessitates appropriate pedagogical strategies that empower learners to

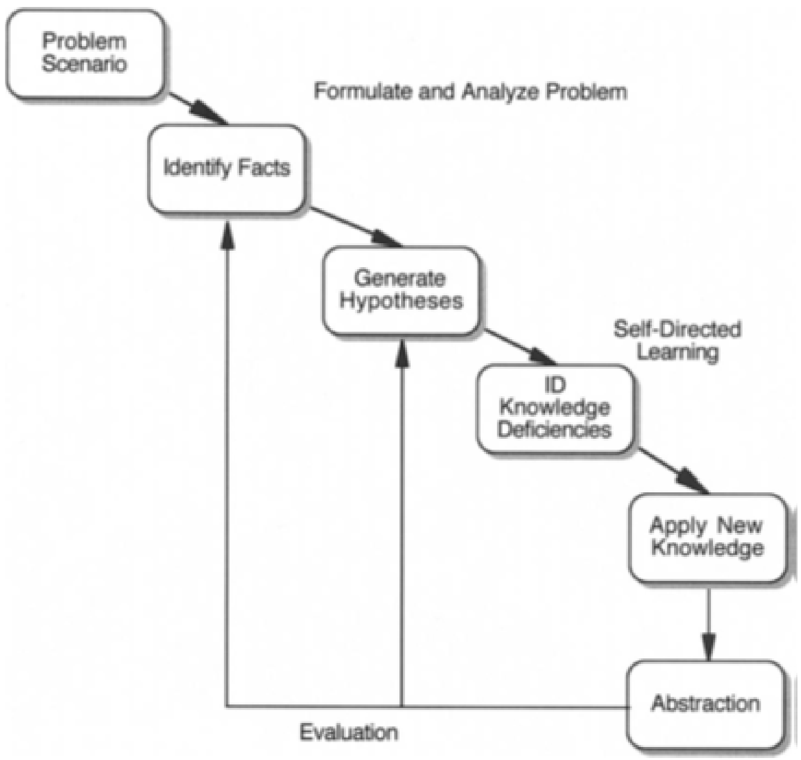


**Figure 1.** Problem-based learning cycle (Hmelo-Silver, 2004)

appreciate systems thinking and act responsibly toward environmental challenges. This goal has sparked growing interest in Problem-Based Learning (PBL) as an active learning approach that fosters learner agency, critical thinking and problem-solving skills- all essential for preparing future generations to address complex environmental issues.

EE is a process that enhances individuals' awareness and understanding of environmental issues, builds competencies to address them and encourage values and commitments that support informed, responsible decision-making (NAAEE, 2021). A foundational document, the Tbilisi Declaration, outlines five key objectives of EE as:

(a) To foster awareness of environmental problems,
(b) To provide knowledge and understanding of the environment
(c) To develop attitudes of concern and motivation
(d) To build skills for problem-solving
(e) To encourage participation in environmental improvement and protection (UNESCO, 1978).

Building on this framework, the North American Association for Environmental Education (NAAEE) includes awareness and sensitivity; knowledge and understanding; attitudes and values; skills for investigation and action; and participation in resolving issues (NAAEE, 2010). Similarly, PBL is described as a student-centered teaching approach in which learners work collaboratively to explore real-world problems, identify solutions, and reflect on their learning process (Barrows & Tamblyn, 1980; Savery, 2006). A classical definition of PBL provided by Howard Barrows states that it is *the learning that results from the process of working towards the understanding of a resolution of a problem. The problem is encountered first in the learning process* (Barrows & Tamblyn, 1980). Within the context of EE, PBL serves as an experiential and inquiry-driven approach that connects environmental concepts with real-world problem-solving, thereby enhancing both knowledge acquisition and action-oriented learning (Hmelo-Silver, 2004). The PBL learning cycle (**Figure 1**) typically consists of key iterative stages:

(1) Problem presentation, where students are introduced to a complex, ill-structured, real-world environmental issue;
(2) Problem definition, where learners identify what they know and what they need to learn;
(3) Generation of hypothesis based on facts already known
(4) Identification of knowledge deficiencies when learners identify information gaps and engage in self-directed learning to gather the relevant information;
(5) Application of new knowledge to develop a solution, where potential solutions are collaboratively developed; and
(6) Abstraction, presentation of solutions and reflection, where students present their findings and reflect on their learning process (Hmelo-Silver, 2004; Savery, 2006).

This iterative learning process empowers students to take ownership of their learning, fosters deep understanding of environmental concepts, and develops critical thinking and problem-solving skills necessary for sustainable action.

At the core of an effective PBL implementation in EE is the concept of Pedagogical Content Knowledge (PCK), which refers to teachers' ability to integrate subject matter knowledge with appropriate instructional strategies towards achieving set instructional goals (Gess-Newsome et al., 2017; Shulman, 1986). Research shows that teachers' confidence and competence in addressing environmental issues are significantly shaped by their PCK (Ferreira et al., 2006; Kim & Fortner, 2006). Aligning teacher PCK with EE learning goals in teacher education and professional development is therefore crucial. However, global assessments of teacher education programs reveal a persistent gap in the integration of EE into teacher education programs (UNESCO, 2021). For example, despite large-scale efforts such as the UNESCO Decade of Education for Sustainable Development (2005–2014) and the ongoing ESD for 2030 initiative, fewer than 50% of teacher preparation programs worldwide adequately equip future educators for environmental literacy and climate action (UNESCO, 2021).

This shortfall in teacher preparation contributes to a broader issue: the well-documented gap between students' environmental knowledge and their actual behaviors. In Malaysia, for instance, Abdullah and Halim (2010) attributed this disconnect to teachers' limited PCK specific to EE despite the integration of EE into the national curriculum since 1998. Although direct empirical evidence linking teachers' PCK to measurable changes in student behavior is still limited, related studies provide supportive insights of the correlation. Eames and Birdsall (2019), for example, found that strengthening teachers' environmental PCK enhanced student engagement and conceptual understanding. Similarly, Lee et al. (2018) demonstrated that targeted professional development can significantly improve teachers' environmental PCK, laying the groundwork for deeper student learning and potentially behavior change.

Moreover, existing research confirms that knowledge alone is insufficient to drive pro-environmental behavior (Hungerford & Volk, 1990; Kollmuss & Agyeman, 2002). Factors such as school culture, community norms, and policy contexts all shape whether environmental knowledge translates into meaningful action. In this regard, pedagogical approaches that actively engage students (such as experiential learning, community-based projects, and inquiry-driven activities) have been shown to foster agency, curiosity and motivate environmental action (Sims et al., 2020). These strategies align closely with the principles of PBL, which emphasize hands-on learning, collaboration with local communities, and the development of inquiry and problem-solving skills.

Given the persistent challenges and the growing need for more effective EE, PBL is increasingly recognized as a promising strategy for preparing learners by fostering environmental literacy and action. By placing learners at the center of the learning process to work towards resolving real-world environmental problems, PBL enables them to investigate relevant environmental issues, collaborate with peers, and develop solutions through critical inquiry and reflective practice (Hmelo-Silver, 2004).

Despite the implementation of PBL as an EE pedagogy, however, a comprehensive review of its impact on achieving the goals of EE is nonexistent. The purpose of this literature review, therefore, is to explore the use of PBL as an instructional pedagogy in EE and assess its impact on achieving the goals of EE, which include enhancing environmental knowledge, fostering pro-environmental attitudes, and promoting sustainable behaviors. By synthesizing findings from global and regional studies on PBL in EE, this review aims to contribute to the discourse on active learning pedagogies in EE, inform EE practice, and offer recommendations for the effective integration of PBL in EE across educational levels.

# METHODOLOGY

A systematic literature review (Moher et al., 2009; Petticrew & Roberts, 2006) was conducted using Google Scholar, ERIC, and EBSCO Host electronic databases, which together provide access to a broad range of international educational research. The keywords "Problem-Based Learning" and "Environmental Education" were used, with the Boolean search operator ("Problem-Based Learning" AND "Environmental Education") to ensure that only relevant studies were retrieved. Additional relevant publications were identified through snowballing (Greenhalgh & Peacock, 2005), tracing references in articles, and using reverse citation tracking to locate studies citing the initially retrieved articles. Although "sustainability education" and "education for sustainability" are often used interchangeably with EE in the literature, these terms are frequently attached to specific subject areas, such as "sustainable tourism" and "sustainable agriculture". Including these terms in the search would have generated an overwhelming number of results, many of which would fall outside the focus of this review on EE in its broadest sense. For this reason, these terms were excluded from the search strategy. Additionally, the abbreviation "PBL" was not included in the search terms, as it is also used to refer to Project-Based Learning, a distinct but related instructional approach. Including "PBL" would have resulted in irrelevant studies, thereby compromising the focus on Problem-Based Learning in the context of EE.

The search was limited to studies published between 2005 and March 2025 to align with the launch of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Decade of Education for Sustainable Development (DESD) from 2005 to 2014, which promoted sustainability in education (UNESCO, 2005). This timeframe also captures developments in EE in subsequent initiatives such as the Global Action Program on Education for Sustainable Development from 2015 to 2019 (UNESCO, 2012, 2013). Keywords were searched across the full text of the papers, rather than being confined to the title or abstract. An initial search generated a total of 12,986 results: 12,800 from Google Scholar; 167 from ERIC and 23 from EBSCO Host. Titles were first scanned to remove duplicates and titles outside the focus of the review. The results were further screened to only include peer-reviewed articles that undertook empirical research. Books chapters, reports and paid articles were excluded. The application of this criterion brought the results down to 1,163. Abstracts of the remaining articles were then carefully perused to ensure studies contained the use of PBL as pedagogy for EE, and full articles were available in English language. In line with the criteria presented in **Table 1**, studies were screened in two stages:

(1) Title and abstract review and
(2) Full-text review.

Specifically, papers were excluded from the analysis if they:

(a) Did not explicitly discuss the use of problem-based learning in EE or environmental science
(b) Had irrelevant educational contexts -focusing on informal or other non-school settings
(c) Did not present empirical study results, were book chapters, or institutional reports
(d) Older studies published before 2005
(e) Were not published in English.

**Figure 2** illustrates the articles search, retrieval and screening process.

**Table 1.** Inclusion and exclusion for criteria article selection

| Criterion | Description | Exclusion criteria | Rationale |
|---|---|---|---|
| Topical relevance | Articles that explicitly focus on PBL within the context of environmental education in formal learning settings. | Articles that do not apply PBL or are unrelated to environmental or sustainability education. | Ensures conceptual alignment with the review's core focus on PBL in EE. |
| Empirical research | Articles presenting original empirical findings (qualitative, quantitative, or mixed methods), including rigorous systematic reviews. | Theoretical papers, editorials, conceptual discussions, or works lacking data collection and analysis. | Empirical focus allows for evidence-based synthesis of PBL impacts. |
| Publication type | Peer-reviewed journal articles, with exceptions for select high-quality empirical theses and conference papers. | Book chapters, dissertations without empirical components, non-peer-reviewed sources, or grey literature. | Prioritizes quality and credibility; allows for flexibility in under-researched or emerging areas. |
| Date of publication | Articles published between 2005 and 2025 to reflect current understandings and practice. | Studies published prior to 2005 or with insufficient publication status (e.g., unpublished drafts). | Ensures relevance to contemporary PBL and EE pedagogy, tools, and global policy shifts. |
| Language | Articles published in English. | Non-English publications. | Ensures accessibility and consistency in the review process. |

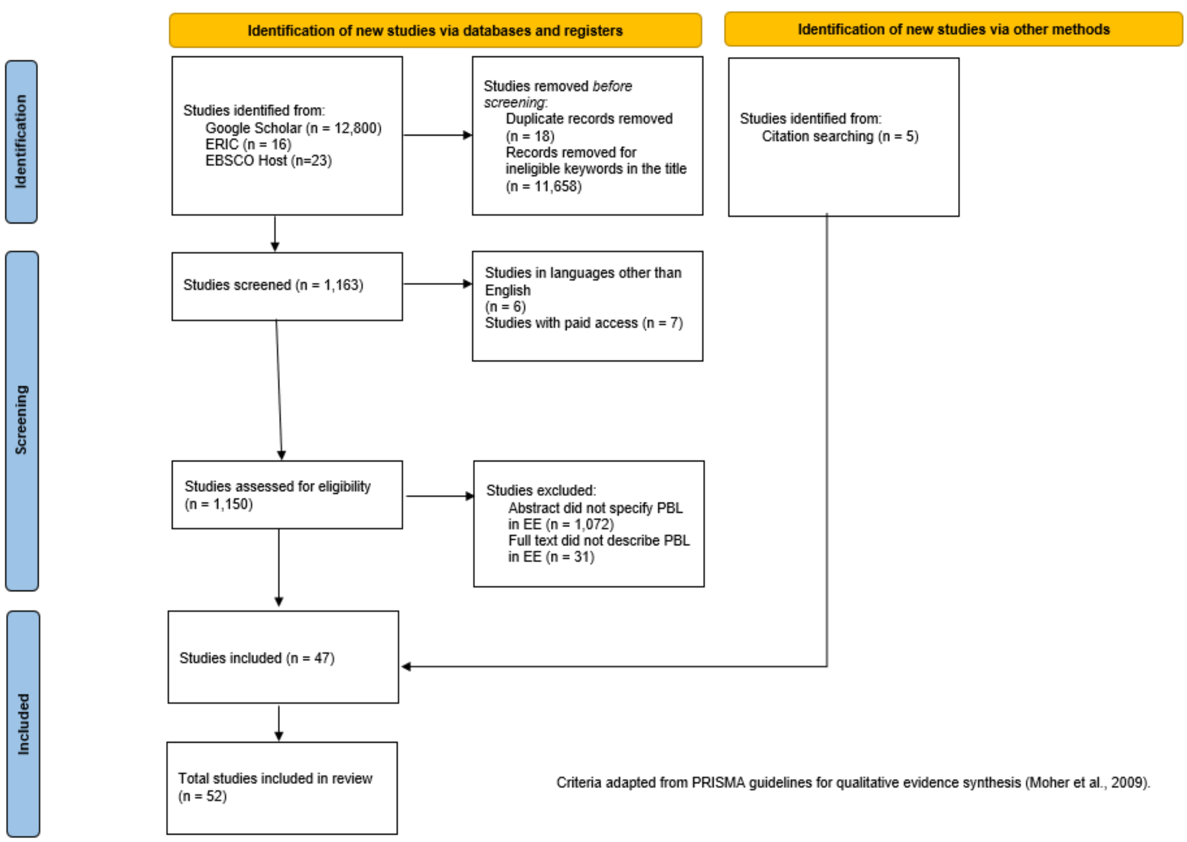


**Figure 2.** Publication retrieval process using the PRISMA framework

Although the inclusion criteria for this review prioritized peer-reviewed journal articles, some empirical studies (thesis, dissertation and conference paper) were included due to their high relevance and methodological rigor. The application of these inclusion and exclusion criteria resulted in 52 empirical articles which were included in this review.

A careful analysis of the 52 selected studies was conducted to extract and synthesize key features, including the date of publication, geographical location, research methodology employed, complementary instructional models used alongside PBL, participant characteristics, primary findings, and authors' recommendations. The results were then systematically organized into emergent themes to provide a structured understanding of how PBL is implemented and studied in environmental education contexts. These themes allowed for a deeper interpretation of patterns, variations, and gaps across literature.

# RESULTS

The purpose of this systematic literature review was to explore the use of PBL as an instructional pedagogy in EE and its impact on achieving the goals of EE, which include enhancing environmental knowledge, fostering pro-environmental attitudes, and promoting sustainable behaviors. This section presents the findings from 52 peer-reviewed articles and is organized around nine key themes:

(1) Trends in PBL and EE publication output,
(2) The geographical distribution of studies,
(3) Research methodologies
(4) Research lines in PBL in EE studies
(5) Participant educational levels and roles,
(6) Duration of PBL implementation and description of PBL sessions
(7) Content areas integrating EE through PBL
(8) Complementary instructional models used together with PBL and
(9) Research outcomes.

**Table 2** provides an overview of the results under key themes.

**Table 2.** Overview of studies across key themes

| Author(s) | Publication year | Country | Research methodology | Participants education level | Content discipline |
|---|---|---|---|---|---|
| Haney et al. | 2007 | USA | Case Study | Teachers | Interdisciplinary (science and non-science) |
| İşeri Gökmen | 2008 | Turkey | Quasi-experimental | Elementary | Science |
| Keil et al. | 2009 | USA | Quasi-experimental | Middle school | Interdisciplinary |
| Gutiérrez-Pérez & Pirrami | 2011 | Italy | Phenomenology | High school | Science |
| Vasconcelos | 2012 | Portugal | Mixed methods | Middle school | Science |
| Dobson & Bland Tomkinson | 2012 | UK | Action research | College-postgraduates | Managing humanitarian aid projects |
| Roy et al. | 2012 | Tanzania | Developmental research | High school | EE |
| Roy et al. | 2014 | Tanzania | Developmental research | High school | EE |
| Redshaw & Frampton | 2014 | UK | Case study | College | Interdisciplinary environmental science |
| Kalnins et al. | 2014 | Latvia | Action research | College | Environmental management systems |
| Dursun et al. | 2015 | Turkey | Quasi-experimental | Middle school | Science and technology |
| Tapilouw | 2016 | Indonesia | Descriptive research | Teachers | Science |

**Table 2 (Continued).**

| Author(s) | Publication year | Country | Research methodology | Participants education level | Content discipline |
|---|---|---|---|---|---|
| Kricsfalusy et al. | 2016 | Canada | Developmental research | College-post graduates | Field skills in environment and sustainability |
| Febriasari & Supriatna | 2017 | Indonesia | Action research | Elementary | Unspecified |
| Adanalı & Alım | 2017 | Turkey | Case study | College-preservice teachers | Geography |
| Bholah | 2017 | Mauritius | Qualitative interpretive | Middle school | Water education |
| Iswandari et al. | 2017 | Indonesia | Quasi-experimental | High school | EFL |
| Kuvac & Koc | 2018 | Turkey | Experimental | College-preservice teachers | Science teaching |
| Wyness & Dalton | 2018 | UK | Ethnography | College | Accounting |
| Suhirman & Yusuf | 2019 | Indonesia | Experimental | High school | Science |
| Adanalı & Alım | 2019 | Turkey | Case study | College-preservice teachers | Geography |
| Pratomo et al. | 2019 | Indonesia | Experimental | College- elementary preservice teachers | EE |
| Rachman & Matsumoto | 2019 | Indonesia | Quasi-experimental | Elementary | EE |
| Amin et al. | 2020 | Indonesia | Quasi-experimental | College | Geography |
| Kirsop-Taylor et al. | 2020 | UK | Case study | College | Political ecologies of land |
| Rachman et al. | 2020 | Indonesia | Mixed methods | Elementary | EE |
| Fettahlıoğlu & Aydoğdu | 2020 | Turkey | Mixed methods | College-preservice teachers | Science |
| Suryawati et al. | 2020 | Indonesia | Quasi-experimental | Middle school | Environmental problems |
| Chai & Swanto | 2020 | Malaysia | Experimental | Elementary | ESL |
| Sueb et al. | 2020 | Indonesia | Quasi-experimental | Middle school | Environmental science |
| Rachman & Kodama | 2020 | Indonesia | Quantitative descriptive | Elementary | EE |
| Heystek | 2021 | South Africa | Mixed methods | College-preservice teachers | Education for sustainable development |
| Fradila et al. | 2021 | Indonesia | Developmental research | College-post graduates | Ecology and EE |
| Rachman et al. | 2021 | Indonesia | Experimental | Elementary | EE |
| Arisanti et al. | 2022 | Indonesia | Developmental research | Elementary; teachers; social studies experts | Social studies |
| Wajdi et al. | 2022 | Indonesia | Quasi-experimental | College | Environmental knowledge |
| Amin et al. | 2022 | Indonesia | Quasi-experimental | College | Physical geography |
| Cavadas & Linhares | 2022 | Portugal | Ethnography | College | EE & ecotourism |
| Maulida et al. | 2023 | Indonesia | Experimental | Unspecified | Chemistry |
| Maulina et al. | 2023 | Indonesia | Quasi-experimental | Middle school | Science |
| Gök & Boncukçu | 2023 | Turkey | Quasi-experimental | Middle school | Science |
| Carrió Llach & Llerena Bastida | 2023 | Spain | Case study | College | Integrated biomedicine |
| Boncukçu & Gök | 2023 | Turkey | Developmental research | Middle school | Earth & space science |
| Ayerbe-López & Perales-Palacios | 2023 | Spain | Qualitative interpretive | High school | EE |
| Fahlevi et al. | 2023 | Indonesia | Quantitative descriptive | Middle school | Integrated science |
| Rachman & Matsumoto | 2023 | Indonesia | Developmental research | Teachers | Unspecified |
| Nurwidodo et al. | 2024 | Indonesia | Quasi-experimental | High school | Science |

**Table 2 (Continued).**

| Author(s) | Publication year | Country | Research methodology | Participants education level | Content discipline |
|---|---|---|---|---|---|
| Ramandani et al. | 2024 | Indonesia | Developmental research | Unspecified | Physics |
| Fadilah et al. | 2024 | Indonesia | Developmental research | Unspecified | Environmental change |
| Morais et al. | 2024 | Brazil | Phenomenology | College | Information systems |
| Ardiansyah et al. | 2024 | Indonesia | Quasi-experimental | High school | Geography |
| Maulina et al. | 2025 | Indonesia | Quasi-experimental | Middle school | Climate change |

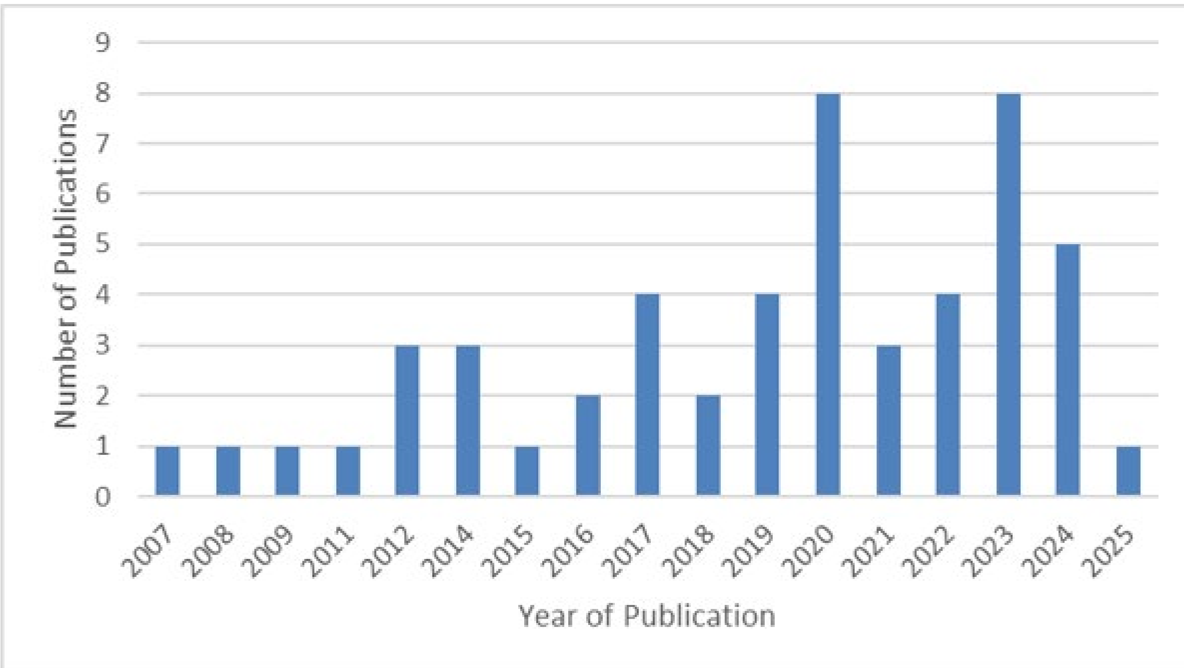


**Figure 3.** Problem-based learning cycle (Hmelo-Silver, 2004)

## Theme 1: PBL and EE Publications Output

An analysis of the 52 peer-reviewed articles revealed a steady increase in publications on PBL in EE from 2007 to 2025 (**Figure 3**). There were no publications in 2005 and 2006. From 2007 to 2011, publication output was minimal, with either one or no publications per year. A distinctive growth pattern emerged from 2012 and 2014, each recording three publications. However, a more sustained growth in activity becomes evident from 2017, peaking in 2020 and 2023 with eight publications each. Although there was a slight dip in 2021 and again in 2024, publication numbers remained relatively high. The single publication in 2025 likely reflects partial data for the year as relevant articles published after March were not included. Early foundational studies, such as Haney et al. (2007) and Vasconcelos (2012), emphasized integrating PBL to enhance environmental awareness and scientific inquiry.

**Table 3** presents detailed information on the authors and the number of publications on the use of PBL in EE from 2007 to March 2025.

**Table 3.** Dates of publication of PBL in EE studies

| Year | Number of publications | Author(s) |
|---|---|---|
| 2007 | 1 | Haney et al., 2007 |
| 2008 | 1 | İşeri Gökmen, 2008 |
| 2009 | 1 | Keil et al., 2009 |
| 2011 | 1 | Gutiérrez-Pérez & Pirrami, 2011 |
| 2012 | 3 | Dobson & Bland Tomkinson, 2012; Roy et al., 2012; Vasconcelos, 2012 |
| 2014 | 3 | Kalnins et al., 2014; Redshaw & Frampton, 2014; Roy et al., 2014 |
| 2015 | 1 | Dursun et al., 2015 |
| 2016 | 1 | Tapilouw, 2016 |
| 2017 | 4 | Adanalı & Alım, 2017; Bholah, 2017; Febriasari & Supriatna, 2017; Iswandari et al., 2017 |
| 2018 | 2 | Kuvac & Koc, 2018; Wyness & Dalton, 2018 |
| 2019 | 4 | Adanalı & Alım, 2019; Pratomo et al., 2019; Rachman & Matsumoto, 2019; Suhirman & Yusuf, 2019 |
| 2020 | 8 | Amin et al., 2020; Chai & Swanto, 2020; Fettahlıoğlu & Aydoğdu, 2020; Kirsop-Taylor et al., 2020; Rachman et al., 2020; Rachman & Kodama, 2020; Sueb et al., 2020; Suryawati et al., 2020 |
| 2021 | 3 | Heystek, 2021; Fradila et al., 2021; Rachman et al., 2021 |
| 2022 | 4 | Amin et al., 2022; Cavadas & Linhares, 2022; Arisanti et al., 2022; Wajdi et al., 2022 |
| 2023 | 8 | Ayerbe-López & Perales-Palacios, 2023; Boncukçu & Gök, 2023; Carrió Llach & Llerena Bastida, 2023; Fahlevi et al., 2023; Gök & Boncukçu, 2023; Maulida et al., 2023; Maulina et al., 2023; Rachman & Matsumoto, 2023 |
| 2024 | 5 | Ardiansyah et al., 2024; Fadilah et al., 2024; Morais et al., 2024; Nurwidodo et al., 2024; Ramandani et al., 2024 |
| 2025 | 1 | Maulina et al., 2025 |

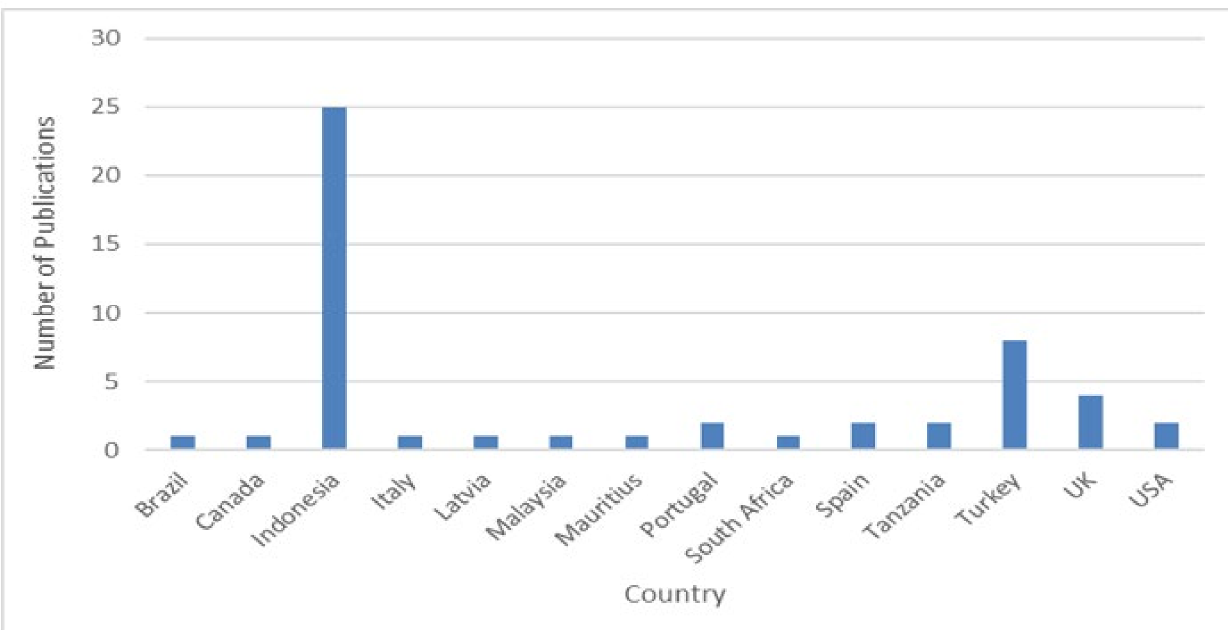


**Figure 4.** Geographical distribution of PBL and EE publications

## Theme 2: Geographical Distribution of PBL in EE Publications

The reviewed publications are heavily dominated by articles from Indonesia, which contributed 25 out of 52 studies representing 48 percent of the total number of articles (**Figure 4**).

**Table 4.** Geographic locations of studies

| Country | Number of studies | Studies |
|---|---|---|
| Indonesia | 25 | Fradila et al., 2021; Suhirman & Yusuf, 2019; Tapilouw, 2016; Ramandani et al., 2024; Suryawati et al., 2020; Fadilah et al., 2024; Sueb et al., 2020; Iswandari et al., 2017; Rachman & Kodama, 2020; Maulina et al., 2023, 2025; Rachman et al., 2020, 2021; Fahlevi et al., 2023; Pratomo et al., 2019; Rachman & Matsumoto, 2019, 2023; Amin et al., 2020, 2022; Febriasari & Supriatna 2017; Maulida et al., 2023; Arisanti et al., 2022; Wajdi et al., 2022; Nurwidodo et al., 2024; Ardiansya et al., 2024 |
| Turkey | 8 | Kuvac & Koc, 2018; Adanalı & Alım, 2017, 2019; Fettahlıoğlu & Aydoğdu, 2020; Dursun et al., 2015; Gök & Boncukçu, 2023; İşeri Gökmen, 2008; Boncukçu & Gök, 2023 |
| United Kingdom | 4 | Kirsop-Taylor et al., 2020; Dobson & Bland Tomkinson 2012; Wyness & Dalton, 2018; Redshaw & Frampton, 2014 |
| Spain | 2 | Ayerbe-López & Perales-Palacios, 2023; Carrió Llach & Llerena Bastida, 2023 |
| Tanzania | 2 | Roy et al., 2012, 2014 |
| USA | 2 | Haney et al., 2007; Keil et al., 2009 |
| Portugal | 2 | Vasconcelos, 2012; Morais et al., 2024 |
| Italy | 1 | Gutiérrez-Pérez & Pirrami, 2011 |
| Canada | 1 | Kricsfalusy et al., 2016 |
| Malaysia | 1 | Chai & Swanto, 2020 |
| Mauritius | 1 | Bholah, 2017 |
| Latvia | 1 | Kalnins et al., 2014 |
| Brazil | 1 | Morais et al., 2024 |
| South Africa | 1 | Heystek, 2021 |

Turkey follows distantly with eight publications, while the UK and USA each contributed four and two publications, respectively. All remaining countries, including Brazil, Canada, Italy, Latvia, Malaysia, Mauritius, Portugal, South Africa, Spain, and Tanzania, each recorded between one and two publications. When grouped by region, Asia accounts for approximately 65 percent of all the publications, led by Indonesia, Turkey, and Malaysia. Europe follows with about 19 percent, with contributions from the UK, Italy, Latvia, Portugal, and Spain. Africa contributes roughly eight percent, represented by South Africa, Tanzania, and Mauritius. North America accounts for about six percent, with publications from the USA and Canada, while South America represents approximately two percent based solely on a contribution from Brazil. This regional distribution highlights a strong concentration of research activity in Asia, with comparatively lower engagement from other regions. **Table 4** presents the full geographic distribution of articles.

## Theme 3: PBL in EE Research Methodologies

The review results revealed a range of research methodologies (**Figure 5**) with a clear preference for quasi-experimental methods which were employed in 15 studies representing about 29 percent of the total number of studies (e.g., Amin et al., 2020; Ardiansyah et al., 2024; Gök & Boncukcu, 2023; Maulida et al., 2023). Developmental or design-based research emerged as the second most utilized approach, appearing in 9 studies (e.g. Arisanti et al., 2022; Boncukçu & Gök, 2023; Fadilah et al., 2024; Fradila et al., 2021; Kricsfalusy et al., 2016) and representing 17 percent of the total number of the studies (**Table 5**). This reflects a focus on the iterative design, implementation, and refinement of educational interventions within real-world contexts. Experimental designs and case studies were each represented in 6 studies (approximately 12% each). Mixed methods approach which employ an integration of both qualitative and quantitative perspectives to explore the complexities of teaching and learning in environmental education, were four and accounted for about eight percent of the total (Fettahlıoğlu & Aydoğdu, 2020; Heystek, 2021; Rachman et al., 2020; Vasconcelos, 2012).

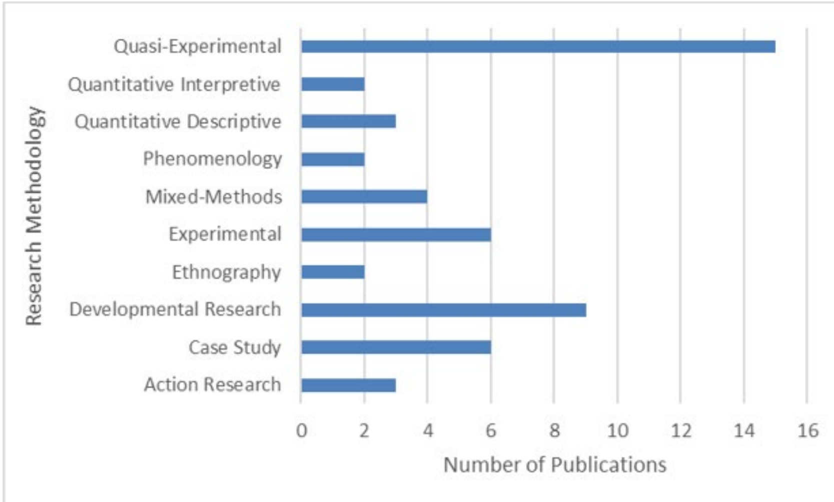


**Figure 5.** Research methodologies used in PBL in EE studies

**Table 5.** Research methodologies employed in PBL and EE studies

| Research methodology | Number of studies | Authors |
|---|---|---|
| Action research | 3 | Dobson & Bland Tomkinson, 2012; Febriasari & Supriatna, 2017; Kalnins et al., 2014 |
| Case study | 6 | Adanalı & Alım, 2017, 2019; Carrió Llach & Llerena Bastida, 2023; Haney et al., 2007; Kirsop-Taylor et al., 2020; Redshaw & Frampton, 2014 |
| Developmental research | 9 | Arisanti et al., 2022; Boncukçu & Gök, 2023; Fradila et al., 2021; Fadilah et al., 2024; Kricsfalusy et al., 2016; Rachman & Matsumoto, 2023; Ramandani et al., 2024; Roy et al., 2012, 2014 |
| Ethnography | 2 | Cavadas & Linhares, 2022; Wyness & Dalton, 2018 |
| Experimental | 6 | Chai & Swanto, 2020; Pratomo et al., 2019; Kuvac & Koc, 2018; Maulida et al., 2023; Suhirman & Yusuf, 2019; Rachman et al., 2021 |
| Mixed-methods | 4 | Fettahlıoğlu & Aydoğdu, 2020; Heystek, 2021; Rachman et al., 2020; Vasconcelos, 2012 |
| Phenomenology | 2 | Gutiérrez-Pérez & Pirrami, 2011; Morais et al., 2024 |
| Quantitative descriptive | 3 | Fahlevi et al., 2023; Rachman & Kodama, 2020; Tapilouw, 2016 |
| Quantitative interpretive | 2 | Ayerbe-López & Perales-Palacios, 2023; Bholah, 2017 |
| Quasi-experimental | 15 | Amin et al., 2020, 2022; Ardiansyah et al., 2024; Dursun et al., 2015; Gök & Boncukçu, 2023; İşeri Gökmen, 2008; Iswandari et al., 2017; Keil et al., 2009; Maulina et al., 2023, 2025; Rachman & Matsumoto, 2019; Sueb et al., 2020; Suryawati et al., 2020; Wajdi et al., 2022; Nurwidodo et al., 2024 |

Less commonly employed methodologies include quantitative descriptive with three studies (Fahlevi et al., 2023; Rachman & Kodama, 2020; Tapilouw, 2016) and action research also with three studies (Dobson & Bland Tomkinson, 2012; Febriasari & Supriatna, 2017; Kalnins et al., 2014), along with more interpretive and qualitative approaches such as phenomenology (Gutiérrez-Pérez & Pirrami, 2011; Morais et al., 2024), ethnography (Cavadas & Linhares, 2022; Wyness & Dalton, 2018), and quantitative interpretive (Ayerbe-López & Perales-Palacios, 2023; Bholah, 2017), each represented by two studies.

## Theme 4: Dominant Research Lines and Study Purposes

A review of the study purposes and research questions in the articles revealed five distinct lines of inquiry in PBL and EE research (**Figure 6**, **Table 6**). The first and dominant line of research was intervention-outcome based representing 46 percent of the studies (n = 24). These include quasi- and experimental studies which

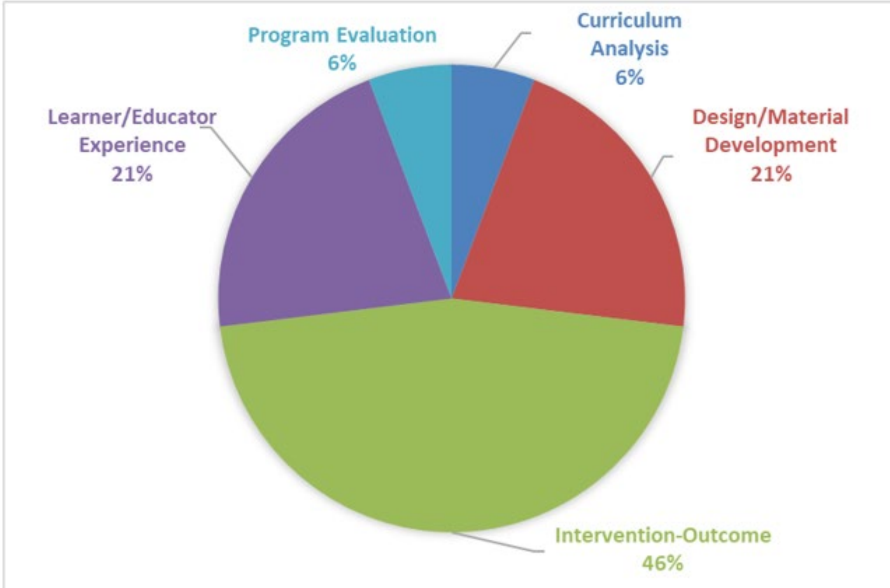


**Figure 6.** Research lines and study purposes in PBL in EE studies

**Table 6.** Research lines and study purposes in PBL in EE

| Research line | Number of studies | Authors |
|---|---|---|
| Outcome-based studies | 24 | Amin et al., 2020, 2022; Ardiansyah et al., 2024; Chai & Swanto, 2020; Dursun et al., 2015; Febriasari & Supriatna, 2017; Fettahlıoğlu & Aydoğdu, 2020; Gök & Boncukçu, 2023; İşeri Gökmen, 2008; Iswandari et al., 2017; Keil et al., 2009; Kuvac & Koc, 2018; Maulida et al., 2023; Maulina et al., 2023, 2025; Nurwidodo et al., 2024; Pratomo et al., 2019; Rachman & Matsumoto, 2019; Rachman et al., 2021; Sueb et al., 2020; Suhirman & Yusuf, 2019; Suryawati et al., 2020; Vasconcelos; 2012; Wajdi et al., 2022 |
| Design/material development | 11 | Arisanti et al., 2022; Boncukçu & Gök, 2023; Fradila et al., 2021; Fadilah et al., 2024; Kricsfalusy et al., 2016; Rachman & Matsumoto, 2023; Ramandani et al., 2024; Roy et al., 2012, 2014 |
| Learner/educator experience | 11 | Adanalı & Alım, 2017, 2019; Bholah, 2017; Cavadas & Linhares, 2022; Gutiérrez-Pérez & Pirrami, 2011; Haney et al., 2007; Heystek, 2021; Kirsop-Taylor et al., 2020; Morais et al., 2024; Redshaw & Frampton, 2014; Wyness & Dalton, 2018 |
| Program evaluation | 3 | Ayerbe-López & Perales-Palacios, 2023; Fahlevi et al., 2023; Rachman & Kodama, 2020 |
| Curriculum analysis | 3 | Kalnins et al., 2014; Rachman et al., 2020; Tapilouw, 2016 |

focused on evaluating the impact of PBL on specific learner outcomes such as critical thinking, environmental literacy, or problem-solving skills (e.g., Amin et al., 2020, 2022; Ardiansyah et al., 2024; Chai & Swanto, 2020; Dursun et al., 2015; Pratomo et al., 2019). Secondly, there were studies (n = 11) which aimed to design or validate PBL-based teaching materials (e.g., Arisanti et al., 2022; Boncukçu & Gök, 2023; Fadilah et al., 2024; Fradila et al., 2021; Kricsfalusy et al., 2016). These studies frequently adopted design-based or development research methodologies and represent 21 percent of the total number. A third research line, also representing 21 percent of the total number (n = 11), explored the perceptions or experiences of learners and educators involved in PBL in EE sessions (Adanalı & Alım, 2017, 2019; Bholah, 2017; Cavadas & Linhares, 2022; Gutiérrez-Pérez & Pirrami, 2011; Haney et al., 2007; Heystek, 2021; Kirsop-Taylor et al., 2020; Morais et al., 2024; Redshaw & Frampton, 2014; Wyness & Dalton, 2018).

The fourth research purpose (n = 3) comprised PBL and EE curriculum analyses and contributed to six percent of the total number (Kalnins et al., 2014; Rachman et al., 2020; Tapilouw, 2016).

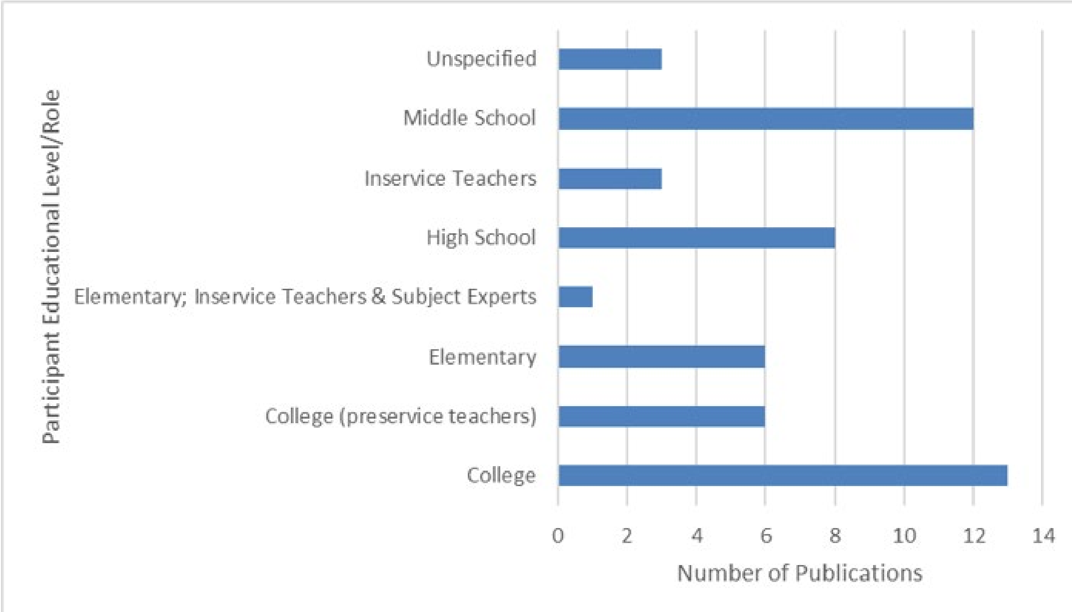


**Figure 7.** Participant educational levels and roles

Finally, another six percent (n = 3) of the research lines provided an evaluation of a PBL in EE program (Ayerbe-López & Perales-Palacios, 2023; Fahlevi et al., 2023; Rachman & Kodama, 2020).

## Theme 5: Participant Educational Levels and Roles

Terminology for grade levels varied across the reviewed studies. For example, seventh-grade students were alternately described as *middle schoolers* or *junior high schoolers*, and *primary* and *elementary* were both applied to fourth- and fifth-grade students. To standardize reporting, this review adopted the following classifications:

(a) Students identified as *junior high* were included under middle school (Grades 7–9);
(b) Students identified as *secondary* were included under high school (Grades 10–12); and
(c) *Primary school* was treated as synonymous with elementary school (Grades 1–6).

An analysis of study participants involved in the reviewed studies revealed a clear emphasis on college undergraduate, middle school and high school populations with comparatively limited attention to teacher-focused and elementary settings (**Figure 7**). College students represented the most frequently sampled population (19 studies, 37%). Of these, 15 studies involved undergraduates and 4 involved postgraduate students (Dobson & Bland Tomkinson, 2012; Fradila et al., 2021; Kricsfalusy et al., 2016; Redshaw & Frampton, 2014). Within the undergraduate population, six studies focused specifically on preservice teachers, and nine examined students enrolled in other majors. Middle school learners (mostly seventh graders) were the second most frequently studied group, appearing in 12 studies (23%), followed not so closely by high school learners (8 studies, 15%).

Elementary learners were featured in six studies (11%), mostly involving fourth and fifth graders, and showing some engagement with PBL at early educational stages. Other participant groups which were less frequently represented were in-service teachers (3 studies, 6%). Only one study (2%) included a multi-stakeholder group of elementary students, in-service teachers, and subject experts (Arisanti et al., 2022). For three studies (6%), (Fadilah et al., 2024; Maulida et al., 2023; Ramandani et al., 2024) the educational levels or roles of the participants were unclear.

**Table 7.** Categorization scheme for PBL implementation durations

| Category | Duration range | Description |
|---|---|---|
| Very short-term | ≤ 4 weeks | Interventions lasting up to four weeks, typically covering brief classroom units or pilot implementations. |
| Short-term | > 4 to 6 weeks | Interventions extending slightly beyond one month but under seven weeks. |
| Medium-term | > 6 to 12 weeks | Interventions conducted over approximately one school term or quarter. |
| Long-term | > 12 weeks to < 1 year | Extended interventions implemented across a semester or more, up to one full academic year. |
| Extended-term | ≥ 1 year | Longitudinal or curriculum-integrated interventions lasting one year or longer. |
| Unspecified | N/A | Studies that did not clearly indicate the duration of the PBL implementation. |

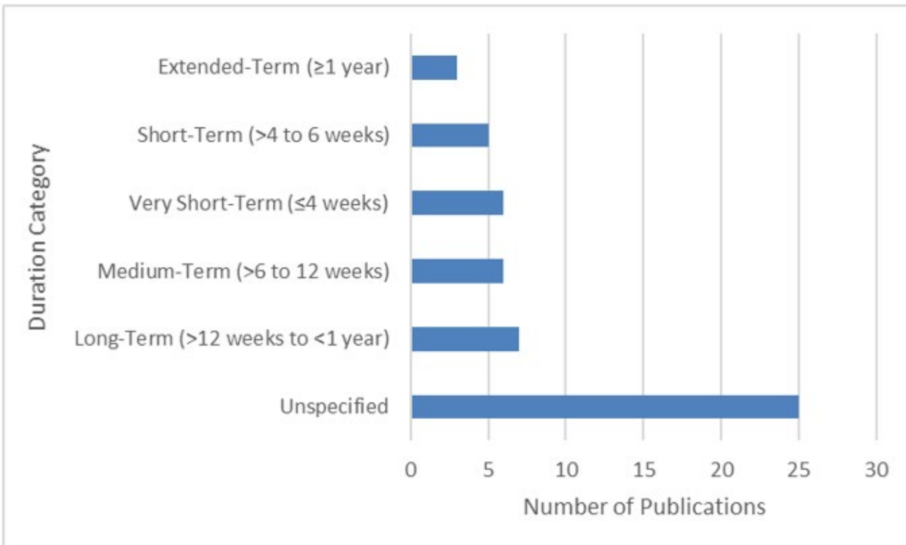


**Figure 8.** Duration of PBL implementation in weeks

# Theme 6: Description and Duration of PBL Implementation

Few authors (n = 9; 17%) provided detailed descriptions of the PBL activities, including the environmental problem addressed, tutorial group size, and frequency of participant engagement (Bholah, 2017; Dursun et al., 2015; Fettahlıoğlu & Aydoğdu, 2020; Gök & Boncukçu, 2023; İşeri Gökmen, 2008; Kalnins et al., 2014; Kuvac & Koc, 2018; Redshaw & Frampton, 2014; Vasconcelos, 2012). Carrió Llach and Llerena Bastida (2023) provided a description in less detail as did Rachman et al. (2020). The duration and structure of PBL implementations varied significantly across studies. To analyze the variation, the reported session durations were systematically categorized based on standardized time ranges commonly used in educational research. Each study's reported duration was standardized into weeks where applicable. The durations were then grouped into five categories as shown in **Table 7**. When the duration is not specified, the study was categorized as *unspecified*. **Figure 8** presents a visual distribution of the categories.

Most of the studies (n = 25, 48%) did not specify the duration of the PBL intervention, indicating a significant gap in reporting that limits comparability and replication. Among studies that did report duration, long-term implementations (more than 12 weeks but less than one year) were the most common (n = 7), accounting for 13 percent of the total. This was followed closely by very short-term implementation (4 weeks or less) and medium-term durations (6 to 12 weeks) both at approximately 12 percent (n = 11). Short-term implementation durations (more than 4 to 6 weeks) were five, representing approximately 10 percent. Extended-term interventions lasting one year or more were the least common, comprising only six percent of the studies (n = 3).

**Table 8.** Thematic coding scheme for broad content areas

| Broad content area | Number of studies | Coding criteria / included topics |
|---|---|---|
| Environmental science | 16 | Studies focused on environmental systems and issues, including ecosystems, sustainability, pollution, conservation, hydrosphere, and water education. This category includes integrated curriculum programs and environmental science instruction across education levels. |
| EE / sustainability | 12 | Studies centered on Environmental Education (EE), Education for Sustainable Development (ESD), ecotourism, and climate change awareness. Emphasis is often on values, attitudes, and sustainable behaviors. |
| General science | 6 | Studies using broad or integrated science frameworks (e.g., "Science," "Integrated Science," "Chemistry," "Physics") not specifically framed as environmental science. Often includes general science teaching at elementary or secondary levels. |
| Interdisciplinary | 6 | Studies combining environmental content with other academic fields (e.g., biomedicine, social science, humanitarian studies) or explicitly described as "interdisciplinary" in design or curriculum. |
| Geography | 4 | Studies addressing physical or human geography, land use, spatial literacy, or environmental topics anchored in geographical concepts. |
| Social sciences | 3 | Studies grounded in social studies, political science, project management, or economics/accounting contexts for EE-PBL integration. |
| Language & communication | 2 | Studies using English as a Second Language (ESL) or English as a Foreign Language (EFL) as the subject through which EE and PBL were delivered. |
| Technology / Systems | 1 | Studies situated in disciplines like information systems, computer science, or environmental management systems. |
| Field Skills / Applied Learning | 1 | Studies emphasizing hands-on or experiential learning in the environment (e.g., fieldwork, sustainability competencies, applied ecological literacy). |
| Unspecified | 1 | Studies where the subject or content area was not clearly stated or identifiable from the publication. |

## Theme 7: Content Areas Integrating EE through PBL

The 52 reviewed articles recorded a wide variety of subject or content areas that integrated PBL in EE. For simplicity, the original subject descriptions were inductively grouped into ten broad categories to reflect thematic and instructional alignment across diverse educational levels. For instance, studies focusing on water-related topics were classified under *Environmental Science* and integrated or general science curricula were grouped under *General Science*. The coding scheme is detailed in **Table 8**. An analysis of these categories revealed a concentration of PBL implementation within traditional science and environmental content areas, with comparatively limited use in non-scientific or applied learning domains. The dominant content area was Environmental Science, which appears in 16 studies, followed closely by EE/Sustainability with 13 studies (**Figure 9**). This suggests that most of the research was concentrated on foundational content directly related to environmental and sustainability issues.

Other subject areas such as General Science**,** Interdisciplinary Studies, and Geography each appear in six studies**,** indicating moderate application of PBL across broader or integrative scientific contexts. Fields like Social Sciences (n = 3) and Language & Communication (n = 2) were less frequently represented, highlighting limited cross-disciplinary engagement. At the lower end, areas such as Technology/Systems**,** Field Skills/Applied Learning, and Unspecified subjects each account for only one study, suggesting minimal exploration of PBL in these contexts.

## Theme 8: Complementary Pedagogies and Instructional Models

A careful analysis of full texts of the 52 articles showed that in 14 of the studies, PBL was amenable to the use of supplemental instructional models and pedagogies. Wajdi et al. (2022) employed the use of comics, Rachman and Kodama (2020) used *Kamishibai*, a Japanese paper theater model, Suhirman and Yusuf (2019)

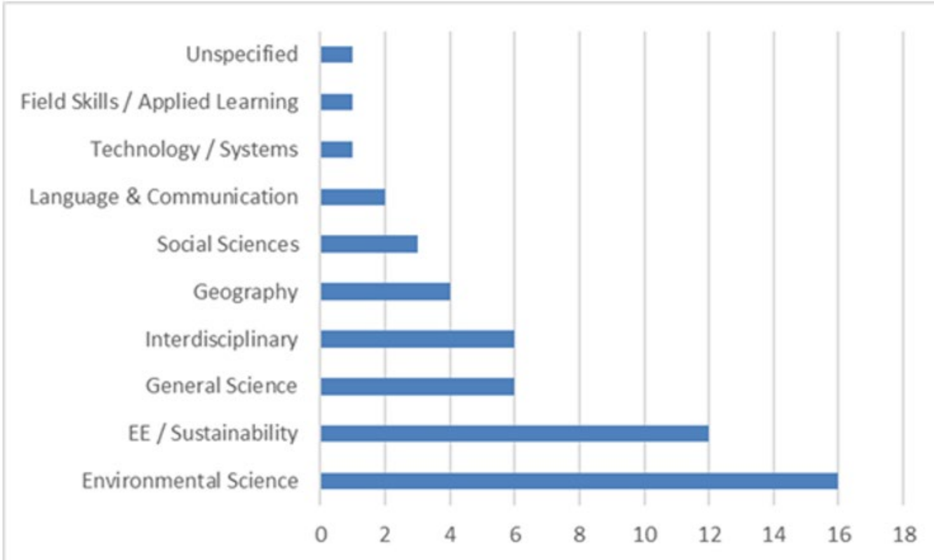


**Figure 9.** Content areas integrating EE through PBL

integrated a naturalist intelligence model and Pratomo et al. (2019) integrated a divergent thinking approach. Regarding classroom learning models, Maulida et al. (2023) reported PBL in EE implementation in a flipped classroom while Amin et al. (2022) reported use in a hybrid learning setting. The integration of Information and Communication Technology (ICT) tools were reported by Roy et al. (2012, 2014) while Fradila et al. (2021) reported the use of a Sigil e-module. Sigil is an application for the management and creation of digital books in the epub format. Additionally, both of Adanalı and Alım's studies (2017, 2019) integrated geocaching (a digital geography-focused game).

Other complementary pedagogies reported included a variant of PBL called Cooperative PBL (Kalnins et al., 2014), Project-Based Learning (Kricsfalusy et al., 2016; Rachman & Matsumoto, 2023) and Service Learning (Kricsfalusy et al., 2016).

## Theme 9: Research Outcomes

A synthesis of the research outcomes reported by the 52 reviewed articles reveal that PBL implementation in EE consistently had positive impacts on participants' environmental literacy, attitudes, problem solving, collaboration and other soft skills (**Figure 10**) with adequate training. While percentages have been used for quantification purposes, they merely reflect the categories. Because many studies address multiple outcomes (**Table 9**), the totals exceed 100 percent. The collective evidence strongly supports PBL as an effective pedagogical approach in EE, particularly in fostering critical thinking and environmental literacy among learners. Numerous studies reported that PBL significantly improves critical thinking skills and abilities to analyze and infer environmental problems (Amin et al., 2020; Ardiansyah et al., 2024; Maulina et al., 2023, 2025). Similarly, improvements in environmental literacy (including knowledge, awareness, and skills) were consistently documented (Febriasari & Supriatna, 2017; Nurwidodo et al., 2024; Rachman et al., 2020, 2021). Beyond cognitive outcomes, PBL appeared effective in cultivating positive environmental attitudes (Gök & Boncukçu, 2023; Kuvac & Koc, 2018). Yet, translating attitude changes into behavior remains challenging. Suryawati et al. (2020) emphasize that for action, PBL problems must include active solutions, indicating that behavioral impact requires intentional incorporation of solution-focused activities in the PBL problem formulation. The development of problem-solving and collaborative skills further distinguishes PBL from traditional approaches. Study outcomes noted enhanced teamwork, communication, conflict resolution,

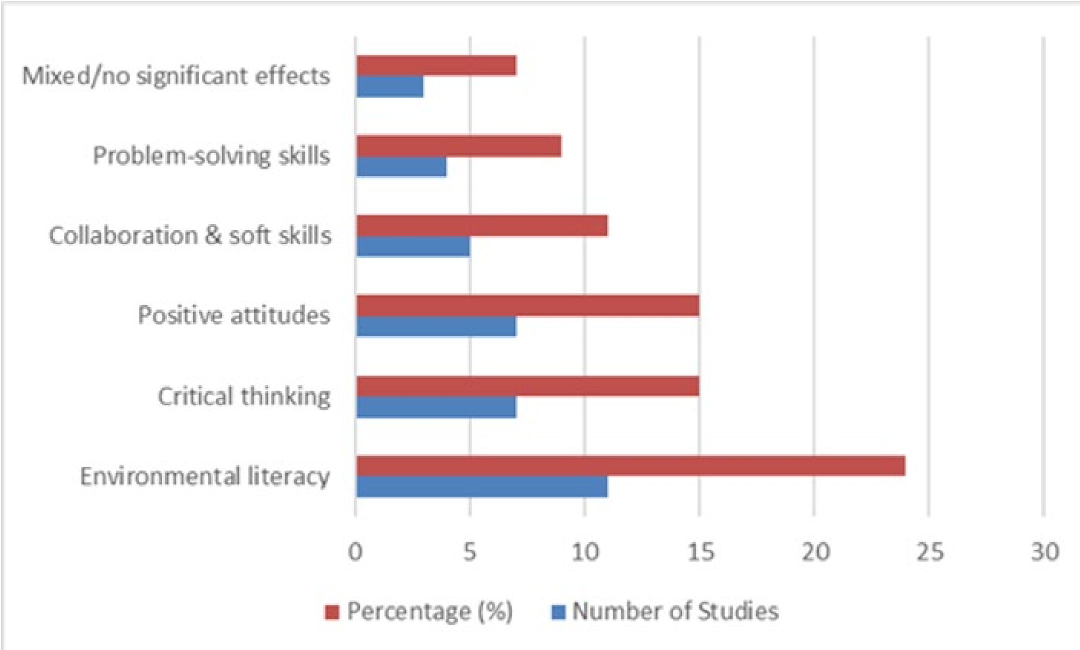


**Figure 10.** Content areas integrating EE through PBL

**Table 9.** Research outcomes by areas of impact of PBL on EE

| Research outcome | Number of studies | Percentage (%) | Authors |
|---|---|---|---|
| Environmental literacy | 11 | 24 | Bholah, 2017; Fahlevi et al., 2023; Febriasari & Supriatna, 2017; Fradila et al., 2021) Gök & Boncukçu, 2023; Iswandari et al., 2017; Nurwidodo et al., 2024; Rachman et al., 2020, 2021; Roy et al., 2012; Sueb et al., 2020; Wajdi et al., 2022 |
| Critical thinking | 7 | 15 | Amin et al., 2020; Ardiansyah et al., 2024; Chai & Swanto, 2020 ; Fadilah et al., 2024; 2025; Maulida et al., 2023; Maulina et al., 2023 |
| Positive environmental attitudes | 7 | 15 | Amin et al., 2022; Dursun et al., 2015; Fettahlıoğlu & Aydoğdu, 2020; Gök & Boncukçu, 2023; İşeri Gökmen, 2008; Kuvac & Koc, 2018; Sueb et al., 2020 |
| Collaboration & soft skills | 5 | 11 | Cavadas & Linhares, 2022; Heystek, 2021; Kirsop-Taylor et al., 2020; Vasconcelos, 2012; Wyness & Dalton, 2018 |
| Problem-solving skills | 4 | 6 | Adanalı & Alım, 2017, 2019; Boncukçu & Gök, 2023; Pratomo et al., 2019 |
| Mixed/no significant effects | 3 | 7 | Adanalı & Alım, 2017; Rachman & Matsumoto, 2019; 2023) |

leadership, and responsibility skills as key benefits (Heystek, 2021; Wyness & Dalton, 2018; Vasconcelos, 2012). Such socio-emotional competencies are critical for equipping learners to navigate complex environmental challenges, particularly in areas such as climate communication, collaborative problem-solving, and organizing for climate justice.

Despite these encouraging findings, however, a few studies (n = 3) reported null or mixed effects (Adanalı & Alım, 2017; Rachman & Matsumoto, 2019, 2023). Variability in outcomes may reflect differences in implementation fidelity, student readiness, or contextual factors. Common barriers included difficulties with ICT competencies, self-directed learning, and group trust (Ayerbe-López & Perales-Palacios, 2023; Gutiérrez-Pérez & Pirrami, 2011). These limitations highlight the importance of scaffolding, gradual introduction of PBL, and ongoing support structures.

Successful implementation of PBL in EE was shown by the research outcomes to depend heavily on adequate training in PBL. For example, Rachman et al. (2020) and Rachman and Matsumoto (2019) found that learner outcomes improved most significantly in experimental groups where both teachers and learners had participated in PBL workshops. Heystek (2021) stressed that proper training of students before implementing PBL for the first time is essential, while tutor roles in providing feedback and scaffolding are crucial especially in hybrid and online learning environments (Vasconcelos, 2012). Without this support, learners may struggle, as noted by Gutiérrez-Pérez and Pirrami (2011), who described learner discomfort with group work dynamics and adapting to novel learning methods. Moreover, learners had better outcomes and were more engaged with PBL problems which were rooted in local contexts (Bholah, 2017; İşeri Gökmen, 2008). İşeri Gökmen (2008) found that learners taught through traditional lectures outperformed those in the PBL group using a non-local environmental problem. The author attributed this unexpected outcome to participants perceiving local issues as more immediate and therefore relevant than global ones, as well as their familiarity with traditional methods and the brief, four-week duration of the PBL intervention.

Time demands, increased workload, and perceived limited institutional support were identified as key challenges to sustaining PBL (Heystek, 2021), highlighting the need for realistic planning and stronger institutional backing. Additionally, contextualizing PBL within the curriculum enhances relevance and effectiveness. Integration with sustainability, climate change, and SDG content showed positive results (Dobson & Bland Tomkinson, 2012; Ramandani et al., 2024). Moreover, the use of tailored instructional materials such as e-modules and worksheets supported learner engagement and comprehension (Fadilah et al., 2024; Fradila et al., 2021;) as did gamification (Adanalı & Alım, 2017, 2019). Comparative studies consistently found PBL superior to traditional lecture-based teaching across a range of outcomes (Chai & Swanto, 2020; Kuvac & Koc, 2018). Notably, seven studies reported that prior to their involvement in the study, participants who included in-service teachers and learners, were unfamiliar with PBL (Adanalı & Alım, 2017; Ayerbe-López & Perales-Palacios, 2023; Nurwidodo et al., 2024; Roy et al., 2014; Suhirman & Yusuf, 2019; Vasconcelos, 2012; Wajdi et al., 2022).

# DISCUSSION

This review reveals distinct patterns in the application of PBL within EE. The temporal trend indicates a growing scholarly interest, with a sharp rise in publications from 2017 onward and peaks in 2020 and 2023. This surge coincides with global educational frameworks promoting sustainability, such as UNESCO's Education for Sustainable Development (ESD) initiatives, suggesting increased alignment between research activity and international sustainability agendas.

In terms of geographic distribution, the findings show a pronounced concentration of studies in Asia, particularly Indonesia, which alone accounts for nearly half of all publications. This regional dominance contrasts with significantly lower research output from Africa, North America, and South America. When analyzed by proportion, Asia constitutes approximately 65% of studies, followed by Europe (19%) and Africa (8%), highlighting global disparities in research engagement with PBL in EE. These disparities may reflect differences in educational policy, funding opportunities, or institutional support for PBL and sustainability education. For example, the strong dominance of studies from Indonesia reflects the country's commitment to integrating EE through the PBL approach, particularly via the Adiwiyata Green School Program (Ardiansyah et al., 2024; Rachman et al., 2020). This leadership is supported by government initiatives and teacher training efforts that promote environmental literacy. Emerging contributions from countries such as Malaysia, Portugal, Brazil, South Africa, and Mauritius signal a growing global interest, yet limited representation from Africa and Latin America suggests the potential value of expanding the research agenda to better reflect a wider range of regional contexts and experiences. Scholars such as Sterling (2010) have argued that sustainability education must be rooted in local realities and socio-ecological conditions, making culturally responsive and place-based PBL in these regions a critical research frontier.

Methodologically, the review shows a clear preference for quasi-experimental designs**,** which appear in more than a quarter of the studies. This suggests a dominant orientation toward outcome-based, interventionist research aimed at demonstrating the efficacy of PBL. While developmental research and experimental designs are also relatively common, qualitative approaches such as phenomenology, ethnography, and interpretive studies are underrepresented. This imbalance may limit understanding of the contextual and experiential dimensions of PBL, especially in diverse educational and sociocultural settings. While quasi-experimental methods offer practical advantages in real-world educational settings, their typically short-term focus may obscure the sustained and systemic impacts of PBL. These limitations highlight the need for more robust, longitudinal, and mixed-method approaches that capture the complex, context-dependent nature of learning in EE. Ethnographic studies in schools already using PBL can also help track long-term behavioral and attitudinal outcomes alongside immediate learning gains. Research lines that explore learner and educator experiences, alongside curriculum-level analyses, are vital to understanding the affective components that promote effective implementation of PBL in EE as well as highlight the need for whole-system transformation and institutional integration to ensure that PBL is not an isolated practice but part of a coherent, supportive educational framework. Together, these research strands would help illuminate the conditions necessary for PBL to achieve its transformative potential in EE.

The review also highlights diversity in participant groups, with middle school, high school and college learners most frequently studied. These populations align well with the self-directed learning demands of PBL (Robinson & Persky, 2020). In contrast, preservice teachers, elementary students, and in-service educators appear less often, despite their critical role in shaping the implementation of PBL in classrooms, presenting a significant gap. As future implementers of pedagogy, preservice teachers' exposure to PBL is essential not only for developing their pedagogical content knowledge (PCK) but also for building confidence in student-centered instructional methods. For example, Haney et al. (2007) recorded significant increases in teachers' self-efficacy, beliefs about the classroom learning environment, and use of reform-based practices after their study. These gains translated into improved student proficiency test scores. Research shows that teachers who experience PBL as learners are more likely to adopt and adapt it effectively in their own classrooms (Magaji et al., 2024). Therefore, expanding the focus on this group will enhance PBL's educational impact in EE. Similarly, early childhood is a formative stage for developing empathy toward nature. Embedding PBL in early grades can help nurture pro-environmental identities (Sobel, 1996), while fostering curiosity, system thinking, and collaborative habits essential for long-term environmental stewardship (Taylor & Kuo, 2006; Tilbury, 1995). It should be noted, however, that appropriate scaffolding is necessary for younger learners; a nuance that might explain the limited representation of elementary grades in literature. For in-service educators, who are central to school-level curriculum implementation, research into their professional development in PBL contexts is vital. Studies such as Weizman et al. (2008) and Lee and Blanchard (2019) emphasize that teacher support, training, and reflective practice are key to effective PBL integration. Therefore, research focus on in-service teachers will help improve outcomes by highlighting how PBL functions in real-world classrooms with varied teaching expertise, time constraints, and institutional challenges. Finally, the scarcity of studies involving multi-stakeholder groups (e.g., students, teachers, researchers) suggests missed opportunities to explore the systemic and collaborative dimensions of PBL, which are essential for addressing complex socio-environmental challenges (van der Leeuw, 2020). Broader engagement across educational roles and levels would enrich our understanding of PBL as a transformative pedagogy in environmental education.

The description of the PBL process and duration of implementation is another area of concern. Nearly half of the studies failed to specify the length of the intervention, while only nine explicitly described their PBL process. This poses challenges for evaluating implementation fidelity and comparing outcomes across studies. This reinforces concerns raised in prior research that insufficient methodological transparency undermines both replication and the evaluation of instructional effectiveness (Walker & Leary, 2009, 2023). The lack of consistency in reporting highlights the need for improved methodological transparency and standardization. Establishing minimum reporting standards, such as those recommended by Phillips et al.'s (2016) Guideline for Reporting Evidence-Based Practice Educational Interventions and Teaching (GREET), could enhance rigor and comparability in PBL-EE research. Without such standardization, it becomes difficult to assess the dose-response relationship between intervention and learning outcomes, a crucial consideration in environmental and sustainability education. Among the studies that did report duration, most were medium- to long-term (6 to 52 weeks), with fewer extended interventions lasting a year or more. This relative scarcity of extended-term (>1 year) interventions may reflect both practical limitations (e.g., school calendar constraints, resource demands) and a lack of institutional support for sustained, transformative learning. Still, long-duration interventions are particularly well-suited to EE goals, as they allow learners to engage in iterative cycles of action and reflection and to develop environmental agencies (Morag et al., 2013).

Content-wise, PBL in EE is predominantly applied within Environmental Science and Sustainability Education, with limited integration into interdisciplinary domains or non-science subjects. While this focus reinforces an increase in EE and sustainability disciplines, it may also signal a persisting limited conceptualization of EE and under-utilizing its cross-disciplinary potential. The marginal inclusion of fields such as social sciences, language and communication, and applied learning limits the exploration of broader competencies such as critical thinking, civic engagement, and collaborative action, which are essential for transformative environmental education (Stevenson, 2007; UNESCO, 2017). Integrating humanities and social perspectives into EE enhances learners' ability to navigate the ethical, cultural, and political dimensions of sustainability challenges. Therefore, the narrow disciplinary focus in PBL-EE applications may hinder the realization of the full educational potential of EE, particularly its transformative and action-oriented dimensions.

The research outcomes consistently demonstrate positive impact of PBL in the core domains of EE: enhancing environmental knowledge, cultivating pro-environmental attitudes, and promoting sustainable behavior change. The alignment between PBL and these EE goals is reinforced by its grounding in constructivist and experiential learning theories, which emphasize active participation and real-world relevance (Dewey, 1938; Kolb, 2014), as well with active learning theories, particularly those emphasizing problem-centered engagement, which have been shown to promote deeper cognitive processing by activating prior knowledge, supporting meaningful learning, and fostering complex reasoning (Barron & Darling-Hammond, 2008; Dolmans et al., 2016; Hmelo-Silver, 2004; Schmidt et al., 2011). What remains largely unexplored are empirical studies that examine the relationship between the use of PBL and measurable improvements in learner environmental action. This gap is critical, as effective environmental education must go beyond the development of knowledge, skills, and positive attitudes; it must also foster learners' capacity and commitment to engage in tangible, pro-environmental behaviors. Without pedagogical approaches like PBL that actively engage students in contextual problem solving and collaborative inquiry, environmental education may fall short of inspiring the transformative actions necessary to address today's urgent environmental challenges and advance a more sustainable future.

In this regard, the integration of complementary pedagogies such as Project-Based Learning (Wiek et al., 2014) and Service-Learning present instrumental opportunities for learners to exercise agency and contribute tangible, context-specific solutions to local environmental challenges. Moreover, the integration of technology such as gamification, flipped classrooms and hybrid learning models offers promising avenues for enhancing learner engagement in the implementation of PBL within EE. However, Selwyn (2012) warns that without addressing the digital divide, such innovations may deepen existing inequities. For under-resourced educational settings, low-cost, community-integrated, and culturally grounded PBL approaches may be more feasible and impactful.

Finally, although PBL has been widely implemented in K–16 education since its inception in medical education in the 1960s, it remains an unfamiliar pedagogy to many teachers and learners, highlighting a persistent gap in both awareness and practice. This was evident in the number of studies where participants experienced PBL for the first time. PBL offers a powerful pedagogical approach for achieving the core goals of EE, particularly in fostering pro-environmental behavior and action. While EE aims to develop knowledge, attitudes, and skills, its ultimate success lies in empowering learners to act (NAAEE, 2019; UNESCO, 2017). PBL aligns with this mandate by engaging students in authentic, real-world environmental problems that require critical thinking, collaboration, and solution-oriented action.

Research shows that PBL not only enhances cognitive outcomes but also supports affective and behavioral domains by making learning personally relevant and socially meaningful (Cebrián & Junyent, 2015). It encourages learners to take ownership of their learning, fostering environmental agency and a sense of responsibility, key predictors of sustainable behavior (Monroe et al., 2017). For example, Fahlevi et al. (2023), who examined the environmental literacy profiles of junior high school students in an Indonesian district, found that most students demonstrated low to moderate levels of environmental literacy. As a remedial measure, the authors recommended the use of PBL to support more targeted and effective environmental instruction. Yet, despite its alignment with EE goals, PBL remains underutilized as an EE pedagogy, indicating a missed opportunity to transform environmental learning into impactful, community-oriented action.

## Implications for Practice and Teacher Education

The findings of this systematic review hold significant implications for EE practice and teacher education. First is the importance of comprehensive preparatory training for both learners and educators to ensure a shared understanding of PBL principles and expectations. This is especially important given the findings of Magaji et al.'s (2024) systematic review, which show that PBL is underutilized in preservice science teacher training, with only a few relevant studies published in this area. Second, PBL facilitators must provide deliberate and sustained scaffolding to support learners' inquiry processes, particularly in navigating complex environmental issues. Third, embedding PBL within relevant and meaningful curricular themes further enhances student engagement and promotes deeper learning. Fourth, effective implementation would require careful planning to balance workload and time demands, as poorly managed pacing can lead to participant fatigue and reduced motivation, ultimately undermining the benefits of the PBL approach. Fifth, the design of PBL problems should intentionally incorporate opportunities for actionable environmental solutions to help bridge the attitude–behavior gap. This can be further strengthened through the integration of complementary pedagogies such as Service Learning and Project-Based Learning (PjBL), which provide real-world contexts for learners to apply their knowledge and skills. The sixth implication requires curriculum developers to appreciate the value of integrating PBL modules with sustainability and environmental themes, supplemented by carefully designed instructional materials tailored to student contexts. Finally, preservice teacher education and in-service professional development programs should prioritize PBL as a core pedagogy in environmental education, given its demonstrated potential to advance key EE goals, including environmental literacy, problem-solving and pro-environmental action.

## Gaps and Recommendations for Future Research

This systematic review has identified several research gaps that warrant further investigation in future studies. First, future research on PBL in EE should adopt a standardized reporting checklist (**Table 10**), to enhance transparency, ensure implementation fidelity, and support reproducibility across diverse educational settings.

This proposed reporting protocol has been adapted from the 2016 Guideline for Reporting Evidence-based practice Educational interventions and Teaching (GREET) checklist, and the Template for intervention Description and Replication checklist (TIDieR) by Hoffman et al. (2014), which is used in medical practice (Hoffmann, 2014).

**Table 10.** PBL implementation reporting checklist for environmental education research

| Item | Description |
|---|---|
| 1. PBL intervention name/title | Provide a clear name or title for the PBL unit or project. |
| 2. Rationale | Explain the educational and environmental relevance of the central problem and why PBL was selected. |
| 3. Learning objectives | State cognitive, affective, and behavioral learning goals aligned with EE outcomes. |
| 4. Problem description | Detail the central problem's environmental context, authenticity, and complexity. |
| 5. Context of implementation | Describe setting, learner characteristics, course structure, and local context. |
| 6. Instructor/facilitator role | Outline who facilitated the sessions, their training, and instructional role. |
| 7. Learner role and grouping | Describe how learners engaged with the problem and collaborated. |
| 8. Duration and frequency | Specify the length and frequency of PBL activities. |
| 9. Materials and resources | List instructional tools, technologies, and content used. |
| 10. Assessment and evaluation | Detail tools and strategies used to measure outcomes. |
| 11. Fidelity of implementation | Describe how fidelity was monitored and maintained. |
| 12. Outcomes and impact | Report both expected and unexpected cognitive, behavioral, and affective outcomes. |
| 13. Challenges and adaptations | Share implementation barriers and how they were addressed. |
| 14. Transferability | Discuss how the intervention may be adapted in other contexts. |
| 15. Theoretical framework | Identify any guiding pedagogical or EE-related theory used in design. |

Other areas of importance in future research include:

(a) Exploring causal impacts of PBL on environmental behavior in longitudinal studies as well as investigate the strategies to mitigate adaptation challenges;
(b) Expanding PBL implementation to underrepresented regions, particularly in Africa and Latin America;
(c) Conducting longitudinal studies that track behavioral and attitudinal outcomes;
(d) Integrating indigenous knowledge systems and community-based learning into PBL models;
(e) Leveraging scalable, low-tech innovations and digital platforms to broaden access, especially for low-income communities; and
(f) Expanding study populations include more elementary students, in-service and pre-service teachers as well as multi-stakeholder groups.

These priorities are essential to scaling the impact of PBL globally and fostering the next generation of environmentally responsible citizens.

# CONCLUSION

This systematic literature review aimed to explore the use of Problem-Based Learning (PBL) as an instructional pedagogy and its potential for advancing the goals of Environmental Education (EE). By synthesizing 52 empirical studies from 2005 to March 2025, this review aimed to contribute to the discourse on active learning pedagogies in EE, inform EE practice and teacher education, as well as offer recommendations for future research.

The findings reveal that PBL effectively supports the core goals of EE, including fostering critical thinking, environmental stewardship, and action-oriented problem-solving skills. Through authentic, student-centered learning experiences, PBL empowers learners to engage with real-world environmental challenges, promoting systems thinking and collaboration, both essential for developing environmentally responsible citizens. However, the review also highlights significant barriers to PBL implementation such as limited regional reach, limited utilization of longitudinal and ethnographic methodologies and lack of a uniform reporting guidelines. To address this gap, a Reporting Protocol for Problem-Based Learning (PBL) Interventions in Environmental Education (EE) has been proposed, a significant and novel contribution to the field to guide future research. By addressing these challenges and equipping preservice and in-service teachers with adequate PBL training, teacher education programs can better prepare future educators to foster environmental literacy and sustainability in their classrooms. This review, therefore, affirms the thesis that PBL holds great potential for transforming EE and calls for intentional efforts to integrate PBL within EE curricula, particularly in contexts where environmental challenges are most pressing.

## Limitations of the Review

While this review provides a comprehensive synthesis of empirical studies on PBL in EE, several limitations should be acknowledged. First, the database selection was limited to Google Scholar, ERIC, and EBSCO Host, which, while broad, may have excluded relevant studies indexed in other databases such as Scopus or Web of Science. Second, the inclusion criteria restricted the review to English-language publications, potentially overlooking valuable studies published in other languages, especially from regions where EE is actively evolving. Third, the search strategy deliberately excluded terms like “sustainability education” or “education for sustainability” to maintain focus on EE in its broadest sense. However, this may have led to the omission of conceptually relevant studies using different terminology. Fourth, while peer-reviewed articles were prioritized for rigor, the exclusion of grey literature, such as reports and book chapters, may have limited insights from practice-based and community-driven PBL initiatives. Additionally, study selection was conducted by a single reviewer, which raises the potential for subjective bias in screening and inclusion decisions. Finally, the reviewed studies were predominantly short-term in nature and geographically concentrated in a few countries, notably Indonesia, which may limit the generalizability of findings to other educational contexts. These limitations highlight the need for more inclusive, diverse, and longitudinal research to advance understanding of PBL’s role in global environmental education.

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