What Do We Know About STSE-Based Environmental Education for Indonesian Preservice Early Childhood Teachers? A Blended Systematic Literature Review and Research & Development Study

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HOW TO CITE:

MA. Muazar Habibi, Abdul Kadir Jaelani, Baiq Nada Buahana, Jundu Muhammad Mufakkirul Islami (2026). What Do We Know About STSE-Based Environmental Education for Indonesian Preservice Early Childhood Teachers? A Blended Systematic Literature Review and Research & Development Study. International Journal of Special Education, 41(10s), 1239-1248.

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ABSTRACT:

Background: Preservice early childhood education (ECE) teacher preparation in environmental education remains underexplored in Indonesia. Integrating Science, Technology, Society, and Environment (STSE) approaches addresses this gap. Objectives: This study uses a blended Systematic Literature Review (SLR) and Research & Development (R&D) methodology to synthesize existing research, develop/validate an STSE-based training scenario integrated into scientific thematic lessons, and test its effectiveness on preservice teachers' attitudes.

Methods: The SLR followed PRISMA guidelines across SciSpace, Google Scholar, and Mendeley, screening 242 papers down to 90. The R&D component utilized a 7-stage Borg & Gall model with expert validation, user group testing, and a pre-test/post-test design analyzed via a paired t-test.

Results: The SLR confirmed STSE efficacy, emphasizing experiential learning, local culture, environmental literacy, and infrastructure challenges. The R&D produced a validated training scenario rated 'very accurate,' 'very useful,' and 'very feasible' with 83.3% user acceptance. Effectiveness tests showed a 32.44% improvement in overall positive environmental attitudes.

Conclusion: Grounded in systematic review and rigorous R&D, STSE-based training significantly enhances Indonesian preservice ECE teachers' environmental attitudes. Recommendations include contextualized training programs, policy support, and longitudinal studies.

Keywords: *STSE education; environmental education; preservice teachers; teacher preparation; SETS model.*

1. Introduction

1.1 Background and Rationale

Currently, severe damage to the environment has become a disturbing global situation, largely attributed to inadequate positive environmental mentality and insufficient appreciation of environmental education (Habibi et al., 2021). Environmental degradation, climate change, biodiversity loss, and pollution disproportionately affect vulnerable communities, including children and future generations. In Indonesia, a nation of extraordinary biodiversity and ecological significance, these challenges are particularly acute. Rapid industrialization, urbanization, and deforestation have accelerated environmental decline, while the country's educational system has struggled to keep pace with the need for comprehensive environmental education (Anggraeni et al., 2025; Surjanti et al., 2024).

Early childhood education (ECE) represents a critical window for cultivating environmental awareness, attitudes, and behaviors that persist throughout life (Davis et al., 2020; Eryaşar et al., 2025). Research consistently demonstrates that children who develop positive environmental attitudes in early childhood are more likely to engage in pro-environmental behaviors as adults (Maidou et al., 2019). Consequently, the preparation of ECE teachers to deliver effective environmental education is of paramount importance.

One possible approach to overcome the challenge of environmental degradation is to train prospective early childhood teachers to inculcate constructive behavior towards the environment from a very young age (Habibi et al., 2021). The orientation for prospective ECE teachers is enhanced by modifying early childhood curriculum, incorporating environmental education into academic courses, and providing stand-alone trainings as alternatives for effective and direct implementation (Wicker, 2009).

1.2 The STSE Framework

The Science-Technology-Society-Environment (STSE) model, also referred to as SETS (Science-Environment-Technology-Society) in the Indonesian educational context, provides a holistic framework for understanding the interconnected relationships between scientific knowledge, technological development, societal impacts, and environmental consequences (Binadja, 1999). According to Aikenhead (1992), the STSE model can connect the real-world life of an individual as a member of society with the classroom as a science learning space, providing learning experiences for identifying problems, collecting data, considering alternative solutions, and making informed decisions.

The STSE framework is particularly well-suited to ECE contexts because it: (1) connects abstract scientific concepts to tangible, lived experiences; (2) encourages critical thinking about human-environment relationships; (3) promotes active, inquiry-based learning; and (4) fosters a sense of personal responsibility and agency in addressing environmental challenges (Binadja, 1999; Coyle, 2004). In Indonesia, the STSE/SETS framework has been adopted in various educational contexts, particularly in science education (IPA), though its application in ECE preservice teacher preparation remains limited (Patonah et al., 2017; Yusup et al., 2021).

1.3 Research Gap

Despite the growing recognition of the importance of environmental education in ECE and the potential of STSE approaches, a significant gap exists in the empirical literature. Few studies explicitly examine STSE-based environmental education specifically for Indonesian preservice ECE teachers. Existing research tends to focus on STSE/SETS applications in primary or secondary science education, general environmental education in ECE without STSE integration, or preservice teacher preparation in non-ECE contexts (Pratiwi et al., 2023; Chandrawati et al., 2022). No study has combined a systematic synthesis of the literature with an empirical R&D approach to

develop and validate a contextualized training product for Indonesian preservice ECE teachers.

1.4 Research Questions

This study addresses the following research questions:

What does the existing literature reveal about STSE-based environmental education for Indonesian preservice ECE teachers, including key approaches, strategies, competencies, and contextual challenges?

How can a STSE-based environmental education training scenario be developed and validated for Indonesian preservice ECE teachers?

What is the effectiveness of the developed STSE-based training scenario in improving positive environmental attitudes among preservice ECE teachers?

2. Methodology

2.1 Research Design: Blended SLR + R&D Approach

This study employs a blended methodology that integrates a Systematic Literature Review (SLR) with a Research and Development (R&D) design. The rationale is threefold: (1) the SLR provides a rigorous empirical foundation by synthesizing existing knowledge, ensuring the R&D component is theoretically grounded; (2) the R&D component translates SLR insights into a practical, validated product, bridging the gap between research evidence and educational practice; and (3) the effectiveness evaluation generates new empirical evidence that contributes back to the body of knowledge synthesized in the SLR, creating a virtuous cycle of evidence-based practice development (see Figure 1).

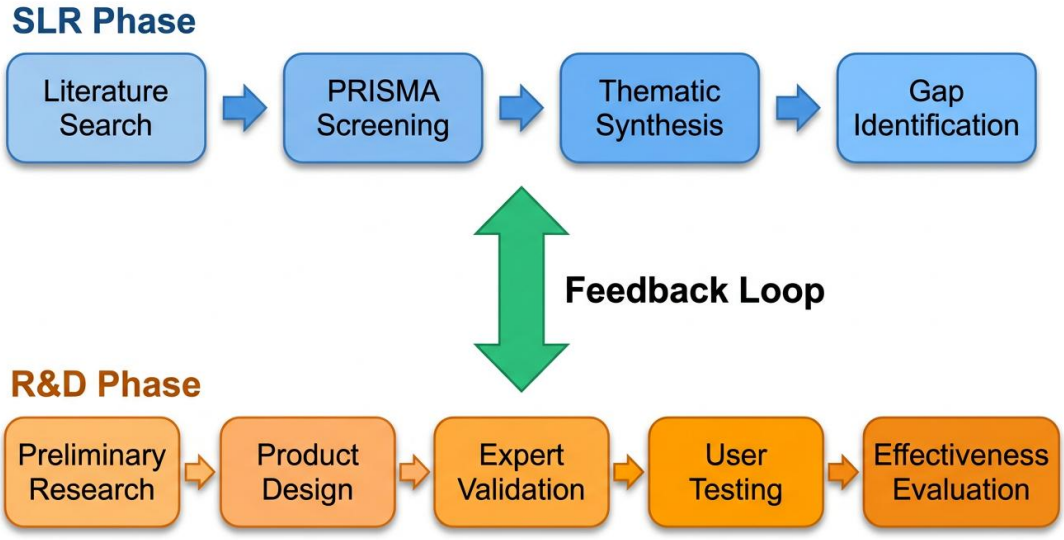

Figure 1. Blended SLR + R&D Research Design Framework

2.2 SLR Component: PRISMA Framework and Search Strategy

Following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, we conducted a comprehensive search across SciSpace, Google Scholar, and Mendeley databases. Keywords and Boolean operators included: 'STSE education,' 'SETS model,' 'environmental education,' 'early childhood education,' 'preservice teachers,' 'teacher preparation,' 'Indonesia,' and 'sustainability education.'

Inclusion criteria encompassed: peer-reviewed journals, conference proceedings, or academic theses addressing STSE/SETS, environmental education, ECE, or preservice teacher preparation; studies conducted in Indonesia or with direct relevance to Indonesian educational contexts; studies published in English or Indonesian. Exclusion criteria included studies

unrelated to education or teacher preparation, studies focusing exclusively on in-service teachers, duplicates, and studies without accessible abstracts.

Three separate searches yielded a total of 242 papers. After merging, deduplication, and AI-powered relevance reranking, 90 papers were included for full review. Data extraction focused on study design, STSE approaches, environmental education strategies, teacher competencies, and Indonesian contextual factors.

2.3 R&D Component: Borg & Gall Development Stages

The R&D component applied the Borg & Gall (2019) development model. Given time constraints and the scope of this study, seven of ten stages were implemented:

Stage 1 — Preliminary Research and Data Collection: Review of existing literature (informed by SLR findings) and needs analysis at PAUD Lenterahati Institution, West Lombok Islamic Boarding School, West Nusa Tenggara.

Stage 2 — Planning: Definition of objectives, competencies, and content scope for the training scenario, integrating STSE principles with scientific thematic lessons.

Stage 3 — Sample Design (Initial Product Development): Development of the training scenario draft, including guidebook, PowerPoint materials, lesson plans, and assessment instruments.

Stage 4 — Primary Field Testing (Expert Validation): Review by three specialists in Early Childhood Education, Environmental Education, and Educational Technology, assessing utility, feasibility, and accuracy.

Stage 5 — Initial Product Revision: Revisions based on expert feedback.

Stage 6 — Further Field Testing (User Group Test): Testing with six undergraduate preservice ECE students through closed interviews and written feedback.

Stage 7 — Operational Product Review: Final revisions and effectiveness evaluation using pre-test/post-test design.

Stages 8–10 (operational testing, final revision, and dissemination) were deferred for future research due to time constraints.

2.4 Data Extraction, Analysis, and Effectiveness Measurement

For the SLR component, data extraction focused on study design, STSE approaches, environmental education strategies, teacher competencies, and Indonesian contextual factors. Thematic synthesis was employed to identify recurring patterns across the included studies. Quality assessment followed established criteria for evaluating educational research.

For the R&D component, the pre-test and post-test instruments were based on Harlen's (1993) environmental attitude scale, measuring four dimensions: (1) concern for the environment, (2) appreciation of the environment, (3) responsibility towards the environment, and (4) attitude to protect the environment. Data were analyzed using a paired-samples t-test.

3. Results

3.1 SLR: Search Results and Study Selection

The PRISMA-guided search and screening process yielded the following results: initial search identified 242 papers across SciSpace, Google Scholar, and Mendeley; after deduplication and relevance reranking, papers were merged and ranked; after abstract screening and application of inclusion/exclusion criteria, 90 papers were included for full review. The included studies encompassed journal articles, conference papers, theses, and book chapters, spanning a range of methodologies including experimental studies, quasi-experimental designs, qualitative case studies, surveys, and conceptual/theoretical papers, predominantly published between 2015 and 2026.

3.2 Theme 1: STSE/SETS Approaches in Teacher Education

The review revealed that STSE/SETS models are increasingly recognized as effective frameworks for improving preservice teachers' environmental attitudes and pedagogical competencies. Studies consistently demonstrated that STSE-integrated instruction leads to: (1) enhanced understanding of science-society-environment interconnections; (2) improved environmental literacy; (3) greater motivation to incorporate environmental themes in teaching; and (4) development of critical thinking skills relevant to environmental problem-solving (Binadja, 1999; Coyle, 2004; Patonah et al., 2017).

In the Indonesian context, STSE/SETS has been applied primarily in science education (IPA) at the primary and secondary levels, with studies showing significant improvements in student learning outcomes and environmental awareness (Yusup et al., 2021). Several studies highlighted the importance of integrating STSE with thematic learning approaches, particularly in ECE contexts where cross-disciplinary, holistic learning is emphasized (Chandrawati et al., 2022; Waluyo et al., 2020).

3.3 Theme 2: Environmental Education Strategies in Indonesian ECE Contexts

The review identified a diverse range of environmental education strategies in Indonesian ECE settings:

Experiential and nature-based learning: Direct engagement with natural environments, including school gardens, outdoor exploration, and community-based environmental projects (Pramitasari et al., 2025; Susilowati et al., 2025).

Local culture integration (ecopedagogy): Incorporating indigenous ecological knowledge and culturally relevant sustainability practices (Pratiwi et al., 2023; Hafman, n.d.).

Project-based and inquiry-based approaches: Encouraging investigation of environmental problems, proposing solutions, and reflecting on outcomes (Anggraeni et al., 2025).

Green curriculum development: Systematic integration of environmental themes, including the Adiwiyata (eco-school) program (Waluyo et al., 2020; Surjanti et al., 2024).

Training and professional development: Targeted training programs including distance learning and community-based approaches (Dewi, 2021; Chandrawati et al., 2022).

3.4 Theme 3: Teacher Competencies for Environmental Education

The review identified several key competencies required for effective STSE-based environmental education in ECE contexts:

Environmental Literacy: Knowledge of ecological systems, environmental issues, and sustainability principles (Yusup et al., 2021; Patonah et al., 2017).

Pedagogical Content Knowledge (PCK): Ability to translate complex STSE concepts into age-appropriate learning experiences (Chandrawati et al., 2022; Davis et al., 2020).

Contextual Adaptation Skills: Capacity to connect global environmental issues with local Indonesian realities (Pratiwi et al., 2023; Hafman, n.d.).

Attitudinal and Motivational Foundations: Positive environmental attitudes, intrinsic motivation, and personal responsibility (Maidou et al., 2019; Eryaşar et al., 2025).

Collaborative and Reflective Practice: Working collaboratively with communities and engaging in reflective practice (Siron et al., n.d.; Arifin et al., 2017).

3.5 Theme 4: Indonesian Contextual Factors and Challenges

The review identified several Indonesian-specific factors shaping STSE-based environmental education implementation:

Infrastructure and Resource Limitations: Many ECE institutions lack adequate facilities and technological resources, particularly in rural areas (Dewi, 2021; Pratiwi et al., 2023).

Inconsistent Teacher Training: Pre-service and in-service programs vary widely in environmental education and STSE coverage (Chandrawati et al., 2022; Waluyo et al., 2020).

Policy Implementation Gaps: While national policies incorporate environmental themes, implementation remains inconsistent at school level (Surjanti et al., 2024; Arifin et al., 2017).

Cultural and Linguistic Diversity: Indonesia's diversity presents both opportunities (rich local ecological knowledge) and challenges (need for culturally responsive approaches) (Hafman, n.d.; Pratiwi et al., 2023).

Limited Research Base: Few empirical studies specifically examine STSE-based environmental education for Indonesian preservice ECE teachers (Patonah et al., 2017; Yusup et al., 2021).

3.6 R&D: Expert Assessment Results

3.6.1 Quantitative Assessment

Three specialists assessed the developed training scenario. The assessment dimensions were utility, feasibility, and accuracy. All three experts rated the product as 'very useful' and 'very accurate.' Feasibility was rated as 'feasible' by the Environmental Education Expert (reflecting the need for contextual adaptations) and 'very feasible' by the Early Childhood and Educational Technology Experts. Results are presented in Table 1.

Table 1. Summary of Expert Assessment Results

Assessment Dimension	Expert I (ECE)	Expert II (Env. Ed.)	Expert III (Ed. Tech.)	Overall Rating
Utility	Very Useful	Very Useful	Very Useful	Very Useful
Feasibility	Very Feasible	Feasible	Very Feasible	Very Feasible
Accuracy	Very Accurate	Very Accurate	Accurate	Very Accurate

3.6.2 Qualitative Assessment

Expert I (Early Childhood Education) affirmed the adequacy of the training brochure and confirmed the training scenario was sufficient for application. Expert II (Environmental Education) provided suggestions for greater clarity of concepts, adaptation beyond elementary school contexts, and more specific environmental education themes — all incorporated in revisions. Expert III (Educational Technology) provided detailed technical recommendations regarding training objectives, visual materials, cover design, and layout consistency, while expressing appreciation for the product's value as a breakthrough in STSE-based environmental education training.

3.7 R&D: User Group Test Results

The user group test involved six undergraduate preservice ECE students. Results are presented in Table 2. Overall, 83.3% of responses were affirmative, indicating strong product acceptance. The only dimension with predominantly negative responses was understanding of the STSE concept (5 of 6 respondents indicated limited familiarity), underscoring the importance of the training itself in building STSE literacy.

Table 2. Tabulation of User Group Field Test Interview Results

Question	Yes (n)	No (n)
1. Is this product easy to understand?	6	0
2. Is this product useful to prospective teachers?	5	1
3. Is this training important for environmental education knowledge?	6	0

4. Can environmental education be integrated into scientific thematic lessons?	6	0
5. Do you understand the STSE concept?	1	5
6. Do teachers need special education for STSE-integrated lessons?	6	0
Total	30 (83.3%)	6 (16.7%)

3.8 R&D: Product Effectiveness Test

The effectiveness test results demonstrated a significant improvement in positive environmental attitudes following the STSE-based training. The overall mean score increased from 2.80 (pre-test) to 3.71 (post-test), representing a 32.44% improvement. Specific gains were observed across all four attitude dimensions measured by Harlen's (1993) scale (see Table 3). The largest gains were in attitudes to protect the environment (+37.69%) and appreciation of the environment (+36.40%), suggesting the training was particularly effective in cultivating affective and behavioral dimensions of environmental attitudes.

Table 3. Pre-test and Post-test Results by Attitude Dimension

Attitude Dimension	**Pre-test Mean**	**Post-test Mean**	**Improvement (%)**
Concern for the Environment	—	—	+21.95%
Appreciation of the Environment	—	—	+36.40%
Responsibility towards the Environment	—	—	+34.94%
Attitude to Protect the Environment	—	—	+37.69%
Overall Positive Environmental Attitude	**2.80**	**3.71**	**+32.44%**

4. Discussion

4.1 Synthesis of SLR and R&D Findings

The blended SLR + R&D design enabled a productive dialogue between systematic evidence synthesis and empirical product development. The SLR established the theoretical and empirical foundation for the R&D component, identifying the effectiveness of STSE/SETS models in improving environmental attitudes and competencies, the importance of experiential and culturally responsive approaches, key competencies required, and the significant gap in empirically validated training products for Indonesian preservice ECE teachers.

The R&D component operationalized these insights into a concrete, validated training scenario, providing proof-of-concept for the feasibility and effectiveness of STSE-based environmental education training in the Indonesian preservice ECE context. The 32.44% improvement in positive environmental attitudes represents a meaningful and practically significant outcome, consistent with findings from comparable STSE interventions reviewed in the SLR (Yusup et al., 2021; Patonah et al., 2017).

The user group finding that 83.3% of preservice teachers found the product useful, but only 16.7% were already familiar with the STSE concept, highlights both the accessibility of the product and the critical need for systematic STSE education in Indonesian ECE preservice programs.

4.2 Implications for Practice

The findings have several important implications for practice:

Integration into ECE Teacher Education Curricula: STSE-based environmental education should be systematically integrated into Bachelor of Early Childhood Education programs in Indonesia, rather than relying solely on stand-alone training events.

Training Program Design: Programs should build STSE literacy from the ground up, combining conceptual introduction with hands-on, experiential learning.

Cultural and Contextual Responsiveness: Programs should explicitly incorporate local Indonesian ecological contexts, cultural practices, and community knowledge.

Collaborative Development: Materials should involve collaboration among ECE specialists, environmental education experts, and educational technology professionals.

Policy Advocacy: Policymakers should prioritize STSE-based environmental education in ECE teacher preparation standards and curriculum frameworks.

4.3 Comparison with Global Trends

The findings are broadly consistent with global trends in ECE environmental education and preservice teacher preparation. Internationally, there is growing recognition of the importance of sustainability-focused teacher education, with STSE and Education for Sustainable Development (ESD) frameworks increasingly adopted in teacher preparation programs (Davis et al., 2020; Eryaşar et al., 2025; Maidou et al., 2019; Wyver, 2022). Compared to studies from Greece, Turkey, and Australia, the Indonesian context is distinguished by the additional complexity of cultural and linguistic diversity, the specific policy landscape (Adiwiyata, K-13), and the particular relevance of local ecological knowledge.

4.4 Limitations

This study has several limitations:

Sample Size: The user group test involved only six preservice ECE students, limiting generalizability. Future studies should involve larger and more diverse samples.

Development Stages: Due to time constraints, Borg & Gall stages 8–10 were deferred.

SLR Coverage: The limited number of studies on STSE-based environmental education for Indonesian preservice ECE teachers reflects genuine scarcity in the field.

Short-term Effectiveness: The effectiveness test measured immediate post-training attitude changes; longitudinal data are not yet available

5. Conclusion

5.1 Summary of Key Findings

This study employed a blended SLR + R&D methodology to advance understanding of STSE-based environmental education for Indonesian preservice ECE teachers. The SLR synthesized 90 papers and identified four major themes: the effectiveness of STSE/SETS models; diverse environmental education strategies in Indonesian ECE contexts; key teacher competencies; and Indonesian-specific contextual challenges. The R&D component produced a validated STSE-based environmental education training scenario, rated as 'very useful,' 'very accurate,' and 'very feasible,' accepted by 83.3% of user group participants, and demonstrated to improve positive environmental attitudes by 32.44% overall.

5.2 Recommendations for Practice

Develop and implement STSE-based environmental education training programs as a core component of Indonesian ECE preservice teacher education curricula.

Ensure training programs are culturally responsive, locally contextualized, and incorporate indigenous ecological knowledge.

Strengthen policy support for STSE-based environmental education through national and regional curriculum frameworks and teacher certification standards.

Foster collaborative partnerships among universities, schools, communities, and environmental organizations.

Expand the developed training scenario to cover broader age ranges and school levels, including elementary school contexts.

5.3 Recommendations for Future Research

Conduct longitudinal studies to examine the persistence of attitude changes and their translation into classroom environmental education practice.

Expand the R&D process to include full operational testing and dissemination stages (Borg & Gall stages 8–10).

Investigate the impact of STSE-based preservice teacher training on children's environmental attitudes and behaviors in ECE classrooms.

Conduct comparative studies across different Indonesian provinces to examine the role of cultural and ecological diversity.

Develop and evaluate digital and distance-learning formats of STSE-based training to address infrastructure challenges in remote areas.

Author Declaration

The authors confirm that this manuscript represents original work and has not been published previously, nor is it currently under consideration for publication elsewhere. Furthermore, the authors state that there are no conflicts of interest regarding the research, authorship, or publication of this paper

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