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# Implementation of Education for Sustainable Development in Elementary School Science Learning: A Systematic Review

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**ABSTRACT**

Rapid global change, including environmental degradation and climate change, demands the strategic role of education in fostering sustainability awareness from an early age. This study aims to systematically review and synthesize research findings related to the implementation of Education for Sustainable Development (ESD) in Natural Sciences (IPA) learning in elementary schools. This study uses a Systematic Literature Review (SLR) approach by following the PRISMA 2020 guidelines to identify, screen, and analyze relevant studies published in the range of 2021 to 2025. Articles are obtained from selected academic databases by applying the inclusion and exclusion criteria that have been set. A total of eleven articles met the eligibility criteria and were analyzed using qualitative thematic synthesis. The findings show that the implementation of ESD in elementary school science learning is generally carried out through active learning models, the development of ESD-based media and teaching materials. All of the studies analyzed reported the positive impact of ESD implementation on cognitive, social-emotional and 21st-century skills aspects. Practically, these findings recommend that primary school teachers integrate sustainability issues through active learning models, project-based activities, and the use of contextual media. In addition, the results of these findings can be a reference for curriculum developers and education policymakers in strengthening the integration of ESD principles in science learning in elementary schools.

**Keywords:** Education for Sustainable Development; Science Learning; Elementary School; Sustainability Literacy; Systematic Literature

## INTRODUCTION

The rapid development of modern society has led to various global challenges, such as climate change, energy crises, environmental pollution, and ecosystem degradation. This condition requires a response from the world of education, starting from the elementary level. In this context, Education for Sustainable Development at the primary school level is an important foundation for instilling sustainability values from an early age through an integrated curriculum [1]. ESD in primary schools is not only oriented towards the providing knowledge about the environment, but also emphasizes the formation of caring attitudes, social responsibility, and critical and collaborative thinking skills that are relevant to the principles of sustainable development [2]. The integration of ESD into the primary school curriculum through thematic learning, cross-subject approaches, and project-based activities allows students to understand the linkages between environmental, social, and economic aspects in a contextual manner [3].

In primary education, science learning has an important role in building scientific literacy and ecological awareness from an early age [4]. Science learning not only aims to introduce basic science concepts, but also instill values, attitudes, and sustainable living skills that are in line with the Sustainable Development Goals, especially SDG 4 (Quality Education) and SDG 13 (Climate Action) [5]. According to Muflikhah, the implementation of the Problem-Based Learning (PBL) model that focuses on Education for Sustainable Development (ESD) at MI Soko Pekalongan has succeeded in increasing science literacy as


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well as students' awareness of sustainability. This problem-based learning approach with the integration of environmental issues encourages students to be more active in internalizing science concepts while building an attitude of caring for the environment. As a result, the method is effective in developing scientific understanding, ecological concern, and sustainable behavior in elementary level students [6].

According to Purnamasari et al., it shows that there are various challenges in the implementation of ESD in science learning. A preliminary study of 25 science teachers showed that the implementation rate of ESD in learning is still around 25%, with limited teachers' understanding of the concept of ESD and Sustainable Development Goals (SDGs) as one of the inhibiting factors [7]. However, according to Mulyadipriana, et al. show that the implementation of ESD through a structured learning approach can have a positive impact on increasing students' awareness of sustainability. Therefore, a systematic study is needed to identify how ESD is implemented in elementary school science learning and its impact on the learning process [8].

The gap between education policy and learning practices in the classroom is an issue that needs to be analyzed more deeply. Although the Independent Curriculum provides space for contextual, collaborative, and project-based learning in accordance with ESD principles, its application in elementary school science learning has not been maximized [9]. Research conducted by Tegar Adinata and Jatmiko Bramantyo shows that topics such as waste management, energy conservation, and climate change are still often taught theoretically without an action-based scientific approach in the environment around students [10]. This shows that there are variations in the application of ESD in science learning that have not been supported by mapping effective implementation patterns and their relationship with desired learning outcomes.

This condition emphasizes the importance of conducting a Systematic Literature Review (SLR) to summarize, compare, and synthesize previous research findings regarding the implementation of ESD in elementary school science learning [11]. Various studies have shown that sustainability-oriented approaches to science learning have the potential to improve students' scientific literacy and environmental awareness. However, these findings are still scattered and show variations in terms of models, strategies, and implementation impacts.

This study aims to formulate a systematic synthesis related to the implementation of Education for Sustainable Development (ESD) in science education (IPA) learning at the elementary school level, which is studied through the systematic literature review method. The focus of the analysis includes the pattern of ESD application as well as the development dimension which includes the cognitive, social-emotional, and competence domains of the 21st century. This study contributes to the literature providing a theoretical synthesis of ESD integration in primary education, as well as offering effective strategies in instilling sustainability values into science learning. The implications of these findings are expected to optimize the development of sustainability-oriented science learning and contribute to the formation of students who have strong scientific literacy and ecological awareness.

## MATERIAL AND METHODS

### Methods

This study uses Systematic literature review (SLR) is a structured, organized, and transparent research methodology to identify, select, and critically assess relevant research

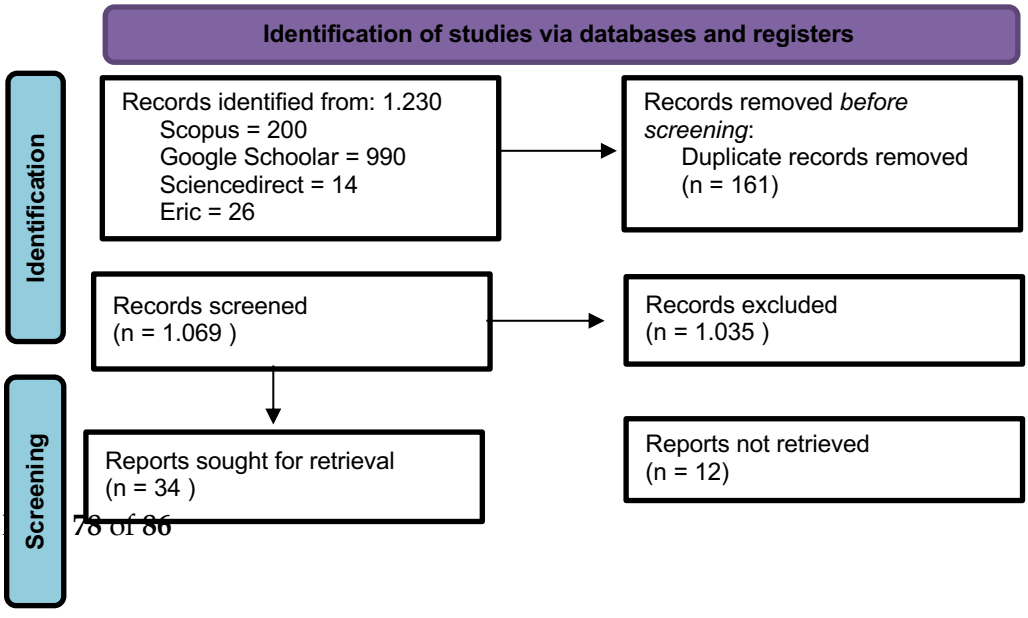
studies to answer specific research questions. This method uses pre-established criteria to select studies, assess their quality, and synthesize their findings. The SLR process is literature search, application of selection criteria, data extraction, synthesis of results, and clear and detailed reporting. This literature review follows the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020, which includes the stages of identification, screening, feasibility assessment, and inclusion of studies to ensure the completeness and accuracy of the process [12].

A systematic and comprehensive literature search was conducted to collect secondary data from relevant sources. Keywords were developed based on the research questions and combine using as boolen operator **("Education for Sustainable Development" OR "ESD") AND ("Science Education" OR "Ilmu Pengetahuan Alam") AND ("Elementary School" OR "Sekolah Dasar").**

The primary databases used were Scopus, Google Scholar, Sciencedirect and ERIC (Education Resources Information Center). Boolean operators were applied to refine search results and ensure relevance. Publications were limited to the period from 2021 to 2025 to ensure the currency of data and research findings included in the synthesis.

**Table 1.** Inclusion Criteria and Exclusion

| Component | Inclusion Criteria | Exclusion Criteria |
|---|---|---|
| Publication Year | Published between 2021–2025 | Published before 2021 |
| Article Type | Empirical research articles or Systematic Literature Reviews (SLR) published in nationally accredited journals (SINTA 1–4) or Scopus-indexed journals | Opinion articles, non-indexed conference proceedings, or non-research reports |
| Research Topic | Studies examining the implementation of Education for Sustainable Development (ESD) in elementary school science learning | Studies not addressing ESD or not conducted at the elementary school level |
| Language | Articles written in Indonesian or English | Articles written in languages other than Indonesian or English |
| Accessibility | Open-access articles | Closed-access or paid articles |



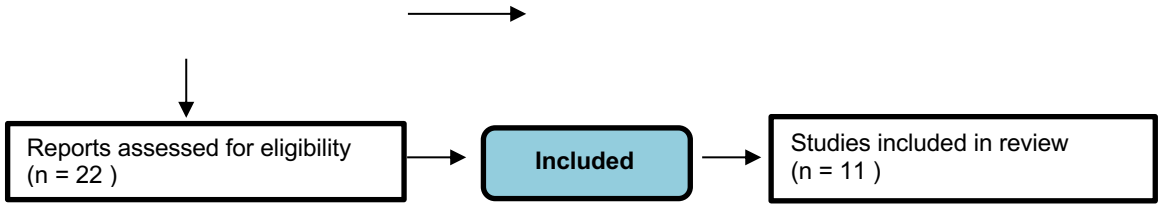



**Figure 1**. Diagram PRISMA 2020

## RESULTS AND DISCUSSION

Based on the literature search and rigorous screening process, eleven articles met the inclusion criteria and were included in the analysis. The extracted data indicate that all selected studies focused on the elementary school level, either within general science learning or sustainability-related science topics.

**Table 2.** Data Extraction Included

| No | Article Title | Journal Index | Authors | Methodology | Findings | Conclusion |
|---|---|---|---|---|---|---|
| 1 | Strategies to Enhance Eco-Friendly Culture and Environmental Awareness by Green Curriculum Integration in Indonesian Elementary Science Classrooms | Quartile 3 Scopus | Arga Triyandana, Ibrahim Ibrohim, Bagyo Yanuwiyadi, Mohamad Amin, Maya Umi Hajar | Implementation of a green curriculum in elementary science learning | Significant improvement in students' environmental awareness and eco-friendly culture | Green curriculum integration systematically embeds ESD values in elementary science learning |
| 2 | The Impact of the ESD-Oriented RADEC Learning Model on Students' Sustainability Consciousness in Elementary School | Quartile 3 Scopus | Hana Lestari, Muhammed Ali, Wahyu Sopandi, Ana R. Wulan, Ima Rahmawati | Pre-experimental study of the ESD-oriented RADEC model | Significant improvement in students' sustainability consciousness | The RADEC–ESD model effectively develops sustainability awareness from an early age |
| 3 | Differentiated Project-Based Learning Model: An Effective | Sinta 2 | Nina Rahayu, Sekar Purbarini Kawuryan, Garib Firman | Quasi-experimental study of differentiated PjBL in | PjBL is more effective in improving students' ecoliteracy than | Differentiated PjBL develops environmental understanding and 21st- |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Strategy in Ecoliteracy Education for Elementary School Students | | Buaga | elementary science learning | conventional learning | century skills |
| 4 | Infusion of the Environmental Dimension of ESD into Science Learning through the RADEC Learning Model in Elementary Schools | Sinta 2 | Hana Lestari, Muhammad Ali, Wahyu Sopandi, Ana Ratna Wulan | Descriptive qualitative study of ESD integration through RADEC | Learning became more active, contextual, and environmentally meaningful | Environmental ESD integration ensures sustainability-oriented science learning |
| 5 | Developing CRT-Based Comic Media to Improve Climate Change Management Education in Elementary School Students | Sinta 2 | Indri Yani, Lungguh Halira, M. Taufik, Indirwan | ADDIE-based R&D for CRT–ESD science comics | Comic media improved students' climate literacy | Comics present ESD issues in a contextual and engaging manner |
| 6 | Development of a Smart Module on the Hydrological Cycle Based on SDGs as a Source of Science Learning for Primary School Students | Sinta 2 | Santa, Suci Siti Lathifah, Delima Nur Aulia, Azzura Gryniprillady Meyradhia | ADDIE-based R&D for smart science modules | Improved learning outcomes and SDGs awareness | SDG-based modules integrate science concepts with sustainable development |
| 7 | An Innovative Approach to Environmental Literacy: The Sustainable RADEC Learning Model for Elementary Schools | Sinta 2 | Hana Lestari, Ima Rahmawati, Mohammad Ali, Wahyu Sopandi, Ana Ratna Wulan | Design and Development Research of the Sustainable RADEC model | The model is feasible and improves environmental literacy | Sustainable RADEC provides a systematic ESD-oriented science approach |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | Development of Geoheritage-Based Media for Education for Sustainable Development to Improve Ecoliteracy in Elementary Schools | Sinta 4 | Dewi Nilam Tyas, Desi Wulandari, Aldina Eka Andriani, Sri Sulistyorini | R&D for geoheritage-based ESD media | Significant increase in students' ecoliteracy | Geoheritage media link science learning with local sustainability issues |
| 9 | Virtual Field Trip Learning Tools Based on Education for Sustainable Development in Elementary Schools | Sinta 3 | Rahmania Zahara, Ghullam Hamdu | R&D for ESD-based Virtual Field Trip tools | VFT tools are feasible and support contextual learning | ESD-based VFTs provide authentic learning experiences |
| 10 | Development of an E-Module on Global Warming Based on Education for Sustainable Development for Elementary Schools | Sinta 3 | Elca Berlianti W.M., Ghullam Hamdu, Agnestasia Ramadhani Putri | R&D for ESD-based e-modules | E-modules increase motivation and conceptual understanding | ESD-based e-modules are flexible and relevant learning resources |
| 11 | Integrating Education for Sustainable Development Principles into Elementary Science Learning to Facilitate Students as Problem Solvers | Sinta 3 | Risda Amini, Yullys Helsa, Afriza Media, Sahrun Nisa, Delfi Eliza | Implementation study of ESD principles | Improved students' problem-solving skills | ESD integration orients science learning toward real-world problem solving |

Based on the literature search and rigorous screening process, eleven articles met the inclusion criteria and were included in the analysis. The extracted data indicate that all selected studies focused on the elementary school level, either within general science learning or sustainability-related science topics. In terms of research methodology, the studies were predominantly characterized by Research and Development (R&D),

experimental or quasi-experimental designs, and qualitative descriptive or implementation studies. Frequently used development models included ADDIE and design and development research, while experimental studies typically compared ESD-based instruction with conventional learning approaches.

The synthesis revealed that ESD implementation in elementary science education is conducted through several key approaches, including the integration of ESD into instructional models such as the ESD-oriented RADEC model and project-based learning (PjBL). Other studies implemented ESD through the development of learning media and instructional materials, including ESD-based comics, SDG-based smart modules, geoheritage-based media, virtual field trips, and global warming e-modules. Additionally, green curriculum integration emerged as a systematic strategy for embedding sustainability values into science instruction.

analyzed studies reported positive impacts of ESD implementation in elementary science learning. Commonly reported outcomes included improvements in environmental awareness, environmental literacy, science literacy, and the development of pro-environmental behaviors. Several studies also reported enhanced sustainability consciousness, problem-solving skills, as well as increased student motivation and engagement. These findings demonstrate that ESD implementation not only supports conceptual understanding of science but also fosters sustainability-oriented attitudes and values among students.

**Discussion**

Based on the synthesis of the literature conducted, this study identified three key findings related to the application of ESD in elementary school science learning, namely: (1) the dominance of active learning approaches as the main strategy for ESD integration, (2) the role of context-based media and teaching materials in supporting the understanding of sustainability concepts, and (3) the impact of the application of ESD on cognitive, socio-emotional, and 21st-century skill development.

1. **Dominance of Active Learning Approaches in ESD Implementation**

   The synthesis reveals that ESD implementation in elementary science learning is predominantly conducted through active learning approaches, such as the ESD-oriented RADEC model and project-based learning (PjBL) [13], [14]. These findings suggest that sustainability integration is more effective when students are actively engaged in learning processes that emphasize exploration, discussion, and contextual problem-solving [15]. Such approaches enable students not only to cognitively understand scientific concepts but also to relate them to real environmental issues in their daily lives [16]. This trend aligns with the fundamental principles of ESD, which position learners as active agents rather than passive recipients of information [17]. Thus, the dominance of active learning models in the analyzed studies indicates that the implementation of ESD in science learning requires pedagogical strategies that can facilitate participation, reflection, and decision-making based on sustainability values from elementary school age.

**2. The Role of Learning Media and Instructional Materials ESD Implementation**

Beyond instructional models, the findings indicate that the development of ESD-based learning media and instructional materials is a frequently employed strategy in elementary science education. Media such as comics, digital modules, virtual field trips, and locally based learning resources help simplify abstract sustainability concepts and make them more accessible to students [18], [19], [20]. Given that elementary students are at the concrete operational stage, sustainability content must be presented in a visual, contextual, and experience-based manner. The use of ESD-based media reinforces the role of science learning as a means of character and value formation, rather than merely conceptual mastery [21]. With appropriate media support, global issues such as climate change, natural resource management, and environmental conservation can be internalized more [22]. Therefore, this finding confirms that the success of ESD implementation is highly dependent on the quality of media design and teaching materials used by teachers in the learning process.

**3. The Impact of ESD Implementation on Cognitive, Socio-Emotional Development, and 21st-Century Skills**

In addition to learning strategies and the use of instructional media, the reviewed studies also indicate that the implementation of Education for Sustainable Development (ESD) has multidimensional impacts on elementary school students' development, particularly in the cognitive, socio-emotional, and twenty-first century skill domains.

From a cognitive perspective, the implementation of ESD has been shown to improve various forms of environment-related literacy, such as environmental literacy, ecoliteracy, climate change literacy, and students' understanding of sustainable development concepts [14], [17], [18], [19], [21], [22]. Several studies report that the use of ESD-based learning resources, such as SDGs-based digital modules, climate change educational comics, and locally based media such as geoheritage, helps students understand the relationship between scientific concepts and sustainability issues in a more concrete way [18], [19], [21], [22]. Through this approach, students not only learn scientific concepts theoretically but are also able to relate them to environmental problems that occur in their daily lives.

From a socio-emotional perspective, ESD-based learning also plays an important role in strengthening environmental awareness, sustainability consciousness, and eco-friendly culture among elementary school students [13], [15], [23]. The integration of sustainability values in science learning encourages students to become more sensitive to environmental issues and to understand the importance of maintaining the balance between human activities and environmental sustainability. Learning activities that address environmental issues can also foster environmental care, a sense of responsibility toward nature, and empathy toward the impacts of environmental degradation occurring around them.

Furthermore, the implementation of ESD also contributes to the development of twenty-first century skills, particularly problem-solving ability, critical thinking, collaboration, and the ability to analyze environmental issues [14], [16], [17], [20]. Learning approaches used in ESD implementation, such as project-based learning, the RADEC model, and experiential learning activities such as virtual field trips,

provide students with opportunities to explore environmental problems directly. Through these activities, students are trained to analyze problems, identify possible solutions, and collaborate with their peers in completing tasks related to sustainability issues.

Overall, these findings indicate that ESD functions as an integrative educational approach that connects knowledge, attitudes, and skills within sustainability-oriented science learning. Therefore, ESD has significant potential to prepare elementary school students to become individuals who possess scientific literacy, environmental awareness, and the ability to address future sustainability challenges.

## Author Contributions

The authors were actively involved in concept development, methodology design, literature search, data collection, data analysis, preparation of the initial draft, and the review and editing process of the manuscript.

## Ethical Considerations

his study did not involve human participants, personal data, or any interventions, and therefore did not require ethics approval or informed consent. All data used in the analysis were obtained from openly published articles, and this study was conducted in accordance with applicable norms and ethical standards for literature review studies.

## CONCLUSION

This systematic review reveals that the implementation of Education for Sustainable Development (ESD) in elementary school science learning is primarily carried out through active learning approaches, including the RADEC learning model, project-based learning, and the integration of sustainability-oriented learning activities. In addition, the findings highlight the important role of ESD-based learning media and teaching materials, such as digital modules, educational comics, virtual field trips, and locally based learning resources, in supporting the integration of sustainability concepts in science learning.

Furthermore, the synthesis of the analyzed studies indicates that the implementation of ESD has positive impacts on elementary school students' development. These impacts include improvements in environmental literacy and scientific literacy, the strengthening of sustainability awareness and environmentally responsible attitudes, as well as the development of twenty-first century skills such as critical thinking, problem-solving, and collaboration. These findings suggest that ESD can serve as an effective approach for strengthening science learning that not only emphasizes conceptual understanding but also promotes environmental responsibility and sustainability awareness among students.

## Limitations and Future Research

This study has several limitations that should be acknowledged. First, this Systematic Literature Review (SLR) is limited to articles published between 2021 and 2025 and sourced from specific academic databases. Therefore, it may not fully reflect all available research on the implementation of Education for Sustainable Development (ESD) in science learning in elementary schools. Second, the analysis in this study emphasized a qualitative synthesis of findings, without engaging in quantitative meta-analysis, given the variety of research designs and outcome indicators used in the evaluated studies.

Based on these limitations, future research is recommended to expand the scope of the study by integrating more databases, a longer period of publication, and more diverse educational contexts. Furthermore, further research could employ a mixed-methods approach or meta-analysis to quantitatively assess the effectiveness of ESD implementation in science learning. Future research could also investigate the long-term impact of ESD-based learning on students' sustainability awareness and pro-environmental behavior at various educational levels.

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