



Systematic Literature Review: Education for Sustainable Development (ESD) in Science Learning to Develop 21st Century Skills

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Abstract

The 21st century demands that learners not only master knowledge, but also critical, creative, collaborative, and communicative thinking skills in response to the global challenges of the industrial revolution era 4.0. However, these skills have not been optimally developed in science learning because learning practices remain teacher-centered and do not provide space for high-level thinking activities that address the low abilities of the 21st century. On the other hand, increasing environmental, social, and economic problems underscore the need for education that fosters sustainability awareness. Education for Sustainable Development (ESD) is a potential approach to integrating 21st-century skills and sustainability values in science learning. However, the implementation of ESD in Indonesia remains limited. It has not been entirely directed toward strengthening 21st-century skills, so a more in-depth study is needed to assess the extent to which ESD has been applied in science learning and its contribution to the development of these competencies. This study aims to analyze the implementation of ESD in science learning to develop 21st-century skills in Indonesia through a Systematic Literature Review of 25 published articles from Google Scholar, Semantic Scholar, and ResearchGate, published between 2020 and August 26, 2025. The article selection process followed the inclusion and exclusion criteria and guidelines of PRISMA 2020, resulting in 25 studies deemed appropriate and relevant. The results of the analysis show that the application of ESD in science learning focuses on developing tools aligned with the learning models used, including Problem-Based Learning (PBL), Project-Based Learning (PjBL), Predict–Observe–Explain (POE), RADEC, and SSCS. The PBL model is the most dominant one because it effectively encourages students to analyze and solve environmental problems scientifically. In addition, most of the research uses e-modules, ESD-based LKPDs, digital media, and virtual field trips as learning media. Based on the analysis of 21st-century skills, critical thinking is the most improved competency (48.3%), followed by sustainability awareness and problem-solving (13.8%), creative thinking and science literacy (10.3%), and environmental literacy (3.4%). ESD integration has been proven to strengthen students' ability to analyze phenomena, evaluate solutions, and make sustainability-oriented decisions. The material topics most often associated with ESD include Environment and Sustainability (44.8%) and Energy and Force (34.5%), reflecting the relevance of climate change, ecosystem, and renewable energy issues in science learning.

Keywords: Education For Sustainable (ESD), Science Learning, 21st Century Skills

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INTRODUCTION

The 21st century is synonymous with the emergence of the industrial revolution 4.0, so this period is often referred to as the era of openness and globalization. In the 21st century, learning is no longer enough to rely solely on knowledge; it also requires the mastery of various skills. Skills are essential in multiple aspects of life (Mardhiyah et al., 2021). 21st-century skills align with the four pillars of education: learning to know, learning to do, learning to be, and learning to live together. Each pillar includes skills to be developed in the learning process,

such as critical thinking, problem-solving, creative thinking, collaboration, information literacy, and others (Zubaidah, 2016).

In the daily learning process, 21st-century skills are still not optimally developed. Learning in the classroom is still dominated by lecture and question-and-answer methods, which tend to make students passive and deprive them of opportunities to think critically, discuss, and solve problems independently. Research by (Maulani et al., 2021) The use of lecture, question-and-answer methods leads to low analytical skills among students. This condition is caused by students' lack of attention during learning, as well as their tendency to be passive, remain silent, and be reluctant to ask questions when they have difficulty understanding the material. This is considered less effective in fostering critical thinking, creativity, problem-solving, and science and environmental literacy skills needed in the 21st century.

In addition, 21st-century skills are closely related to sustainability issues, as students need to be able to understand, analyze, and act on increasingly complex social, economic, and environmental problems. Modern education requires schools not only to emphasize cognitive aspects but also to foster critical thinking, creativity, collaboration, communication, and science literacy skills to address sustainability challenges. Through learning that encourages systemic thinking, students can understand the interconnectedness among the components of life and make decisions and take responsibility. In Indonesia, education oriented towards sustainable development is an essential part of 21st-century competency development (Kemendikbud, 2017). In line with that, research (Azakia & Gunansyah, 2025) It shows that integrating sustainability values into learning can increase students' ecological awareness and problem-solving skills, thereby implementing 21st-century skills.

Learning and Innovation Skills (4Cs) include critical thinking, communication, collaboration, and creativity. These four skills are essential for students to generate new ideas, solve complex problems, and work effectively in teams. This skill is particularly relevant because it helps learners address global challenges, such as climate change and social inequality (UNESCO, 2017). The need to integrate the concept of sustainability into 21st-century skills development stems from the fact that students must be able to innovate to address global challenges and produce real solutions to environmental, social, and economic problems.

One approach to improving 21st-century skills is ESD. *Education for Sustainable Development* (ESD) is an approach that integrates sustainability values and practices to equip students with the knowledge, skills, and attitudes needed to create sustainable lives (Vioreza et al., 2023). ESD views problems through three main pillars: environmental, social, and economic. The pillar is related to global issues and associated with the sustainability of human life. Therefore ESD, it is hoped that students will have sustainability awareness, especially in facing global problems, and think critically about how to overcome a problem by paying attention to the impact that will be caused in various aspects of life (Alissa, 2022).

The concept of *ESD* has been recognized globally as an educational approach that is able to prepare students to face the challenges of the 21st century (UNESCO, 2021). However, the application of *ESD* in science learning remains limited, and further research is needed to optimize its implementation (Rahmawati et al., 2021). This condition indicates that the implementation of *ESD* has not been fully integrated into the science learning process, both in terms of curriculum, learning models, and 21st-century skill development. As researched by (Purnamasari & Hanifah, 2021) highlights that *ESD* can be integrated in science learning through learning tools, learning media, and learning models. However, the study has not specifically examined how 21st-century skills can be systematically developed through this approach. Their research focus remains on the introduction and potential of integrating ESD, without providing an in-depth analysis of effective implementation models for building 21st-century skills. As such, more research is needed to examine the relationship between 21st-century skills and science-based learning *ESD*. This research is essential to ensure that the

implemented curriculum equips learners with the relevant skills to address global challenges and contribute to sustainable development. The following is a formulation of the problem from this study.

1. What 21st century skills can be developed through the integration of ESD in science learning?
2. What is an effective learning model in integrating ESD concepts to improve 21st century skills in science learning?
3. What is the subject matter of the material that can be used to integrate ESD in science learning?
4. What is the overview of the implementation of ESD in science learning?

METHOD

Research Type or Design

This study uses a systematic literature review with a content analysis approach, examining scientific articles on ESD in science learning published in Indonesia from 2020 to August 26, 2025. This study uses the keywords “ESD in Science Learning”, “Science Sustainable Development Education”, “Education for Sustainable Development Science Science”. The sample for this research consisted of 25 articles. These articles were published in the field of ESD in science learning in 2020–August 26, 2025, and are available in the Google Scholar, Semantic Scholar, and ResearchGate databases. To ensure that the analyzed articles are relevant to the research objectives, this study applies inclusion and exclusion criteria as the basis for the literature selection process. Explicit inclusion and exclusion criteria are essential to minimize selection bias and ensure reproducibility in systematic reviews (Booth et al., 2021). This criterion is designed to filter articles that fit ESD topics in science learning. The following are the inclusion and exclusion criteria in this study:

Table 1. Inclusion and Exclusion Criteria

Yes	Category	Inclusion Criteria	Exclusion Criteria
1	Publication Type	Research articles published in Journal	Articles published in conference proceedings, books, websites or blogs, etc.
2	Year of Publication	Articles published in the last 5 years (2020–2025)	Articles not published in the previous 5 years (2020–2025)
3	Research Topics	A study that discusses <i>Education for Sustainable Development (ESD)</i> in Natural Sciences (IPA) learning	Studies that discuss beyond <i>Education for Sustainable Development (ESD)</i> in Natural Sciences (IPA) learning
4	Keywords	<i>Education for Sustainable Development (ESD)</i> ; Science Learning; 21st century skills	Articles that don't have keywords: <i>Education for Sustainable Development (ESD)</i> , Science, 21st century skills or context are not appropriate and relevant
5	Language	Indonesia and the UK	Languages other than Indonesian and English
6	Accessibility	Articles available in open access of the entire text	Articles that are closed to access or only part of the text
7	Research Place	Indonesia	Outside Indonesia

Publication bias in systematic reviews mostly occurs during the selection process. Therefore, a transparent selection process is needed in this study to avoid such biases. For systematic reviews or meta-analyses, the PRISMA 2020 statement is recommended, as it provides readers with more comprehensive and up-to-date guidelines for the selection and

reporting process. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, reporting checklists, and study flow diagrams from 2009 were updated and published in March 2021 as PRISMA 2020. This editorial aims to present the roles and requirements of subjective narrative review articles, systematic literature reviews, systematic reviews and meta-analyses, and to introduce the revisions and objectives of the PRISMA 2020 guidelines (Page et al., 2021).

In research (Rethlefsen & Page, 2022), the PRISMA 2020 guidelines were used to improve the quality and transparency of reporting for systematic reviews and meta-analyses. PRISMA 2020 is a set of evidence-based minimum items designed for systematic reporting and meta-analysis. The PRISMA procedure includes identification, screening, and inclusion. In this study, the PRISMA diagram was used to ensure transparency in the flow of information from collection to filtering to article. The following is a stream of information with PRISMA guidelines for this study:

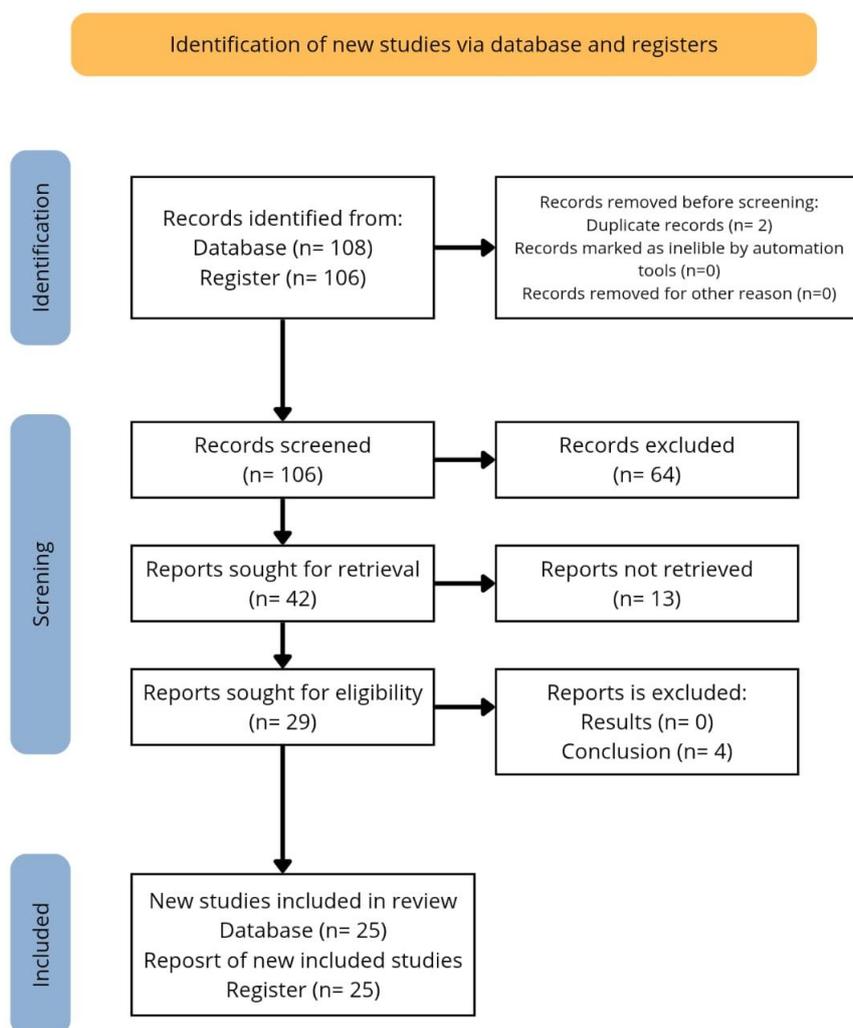


Figure 1. Research Flow using PRISMA

The flow of this research proceeds through three stages. The first stage is identification. This stage involves searching for keywords. At the identification stage, the researcher obtained as many as 108 articles from Google Scholar, Semantic Scholar, and ResearchGate based on keywords matching the research title, and identified two duplicate articles, so 106 articles were entered. The second stage is screening. At the screening stage, out of the 106 articles identified earlier, only 42 articles were declared to have passed after being selected based on titles and abstracts. Then the researcher collected 29 articles that met all eligibility and relevance criteria, based on the ESD approach tested with students. There are 13 articles not included: 5

discussing the validity of modules, 4 discussing the potential of ESD through interviews, 3 on school profiles, and 1 on learning outcomes. In the third stage, namely inclusion, the researcher collected 25 articles that met all criteria. 4 articles are not included because they only test the feasibility of modules that have not been tested. These 25 articles were then used as the basis for further analysis of the research.

RESULTS AND DISCUSSION

The application of ESD in science learning is a strategic step in preparing students to face the challenges of the 21st century. *ESD* plays an essential role in fostering critical thinking skills, environmental awareness, and social responsibility that are the basis for 21st-century skills development (UNESCO, 2021). In the project's principle of strengthening the profile of Pancasila on contextual principles, it is hoped that the surrounding environment and the realities of daily life can be used as the primary learning material (Fatimah & Haryati, 2024). This makes science education an integrated *ESD*. It not only emphasizes mastery of scientific concepts but also encourages learners to apply sustainable values and actions in daily life. According to (Rahmawati et al., 2021), the learning models and methods used have not instilled *ESD* perspective values in learning activities. Therefore, a learning model is needed that can connect scientific knowledge to real-world sustainability practices.

21st century skills can be developed through the integration of ESD in science learning

21st-century skills that can be developed through ESD-based learning include critical thinking, creative thinking, science literacy, environmental literacy, and sustainability awareness. UNESCO (2021) emphasized that ESD encourages the development of transformative competencies such as systemic thinking, critical reflection, and active participation in social and environmental issues. This shows that 21st-century skills are not only an add-on outcome but are at the core of ESD-based science learning, as both concepts emphasize critical thinking and responsible action towards sustainability awareness. 21st-century skills that can be developed through the integration of ESD into science learning include critical thinking, creative thinking, problem-solving, sustainability awareness, science literacy, and environmental literacy. Some of the 21st-century skills often used in ESD in science learning are shown in Table 2.

Table 2. Results of Analysis and Review of Articles Based on 21st Century Skills

21st Century Skills	Sum	Reference
Critical Thinking	13	(Amelia et al., 2025), (Nurasiah, 2025), (Amsal et al., 2025), (I. Fatimah et al., 2022), (Afwah et al., 2024), (Novianti et al., 2023), (F. N. U. Fatimah et al., 2023), (Lestari & Rahmawati, 2022), (Najwa, 2023), (Jamaludin, 2022), (Vilmala et al., 2025), (Muntamah et al., 2024), (Damayanti et al., 2025).
Creative Thinking	3	(Rohmawati et al., 2023), (Lestari & Rahmawati, 2022), (Najwa, 2023)
Problem Solving	4	(Azakia & Gunansyah, 2025), (Pradipta & Hariyono, 2021), (Najwa, 2023), (Pratiwi & Widowati, 2024)
Sustainability Awareness	4	(El Magheest & Suryanti, 2025), (Laela et al., 2024), (Hikmah & Suratmi, 2025), (Muflikhah, 2023)
Science Literacy	3	(Kiswanda et al., 2022), (Sari et al., 2024), (Dieni et al., 2022)
Environmental Literacy	1	(Zulfah et al., 2024)

Based on the table, the most researched 21st-century skill is critical thinking, with 13 studies. This shows that the ability to analyze, evaluate, and make logical decisions remains the primary focus of learning development. Meanwhile, problem-solving skills and sustainability awareness were each identified in 4 studies, suggesting that both are considered necessary, especially in addressing environmental issues and real-life challenges. Meanwhile, creative thinking skills and science literacy were examined in 3 studies each, showing that the development of new ideas and the ability to understand scientific concepts remain relevant. However, they are not yet top priorities. Environmental literacy was found only in one study, suggesting that this skill is still rarely explored in learning-related research. Overall, this table illustrates that educational research places more emphasis on strengthening critical thinking skills but still accommodates a variety of other skills needed in the 21st century. Distribution of the 21st-century skills often used in ESD in science learning are shown in figure 2.

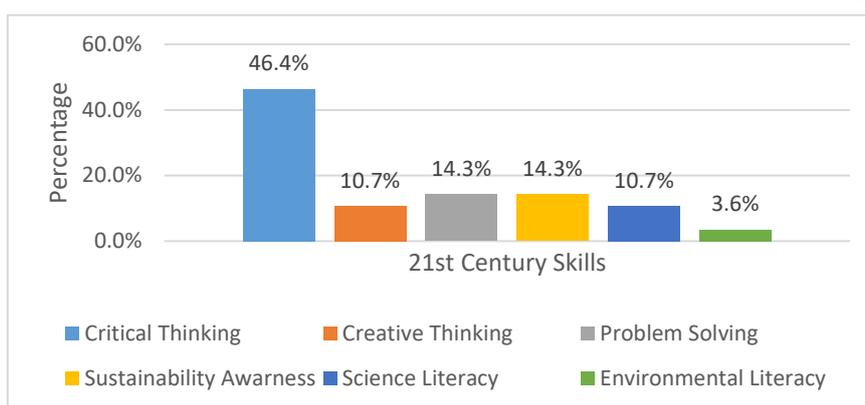


Figure 2. 21st Century Skills Distribution

Based on the 21st Century Skills Distribution Chart, the most dominant is critical thinking with a proportion of 46.4% ($n=13$). This shows that most research on *ESD* in science learning focuses on developing students' critical thinking skills. Critical thinking skills are essential to help students analyze environmental issues, assess information logically, and make sustainable decisions. Furthermore, sustainability awareness and problem-solving skills ranked second, with a proportion of 14.3% ($n=4$), followed by creative thinking and science literacy, each with a proportion of 10.7% ($n=3$), and finally environmental literacy skills, with a proportion of 3.6% ($n=1$). Although the amount of research on creative thinking skills, science literacy, and environmental literacy is relatively small, all three still play an important role in supporting contextual and sustainability-oriented learning.

The results of analyses of various studies on 21st-century skills show that critical thinking is the most dominant competency in the context of integrating *ESD* into science learning. 13 studies report increases in critical thinking skills following the implementation of *ESD*-based learning. The overall results show that integrating *ESD* into science learning is effective in improving students' critical thinking skills. This approach helps students understand the relationship between science concepts and environmental sustainability issues, thereby encouraging awareness and responsibility for the real problems around them. Research conducted by (F. N. U. Fatimah et al., 2023) using critical thinking indicators based on the revised Bloom Taxonomy at the C3 to C6 levels. Integration of *ESD* in the process of analysis (C4) and evaluation (C5) for the development of students' critical thinking skills. In research (Damayanti et al., 2025), the critical thinking indicators, based on Ennis (2011), include: giving simple explanations, building basic skills, concluding, providing further explanations, and setting strategies. Integration *ESD* is used in every critical thinking indicator. Integration *ESD* is strongest in the indicator of managing strategies, because in this indicator, students are asked to act on climate change issues that can trigger real student actions. The weakest integration is in the indicator of giving a simple explanation, because students are only presented with

pictures about climate change, and are not given a simple explanation. This study is effective in improving critical thinking skills, resulting in an N-gain of 0.855 in the high category.

In addition, creative thinking skills are also an important aspect developed through the application of ESD. From the overall research analyzed, there are three studies that show an increase in students' creative thinking skills, namely research conducted by (Rohmawati et al., 2023), (Lestari & Rahmawati, 2022) and (Najwa, 2023). The three studies show that ESD-based learning is effective in improving students' creative thinking skills, primarily through activities that encourage the submission of new ideas and the creation of innovative solutions to sustainability issues. In research (Rohmawati et al., 2023), the creative thinking indicators used refer to the framework developed by Munandar (2009). There are five indicators of creative thinking, including original thinking (originality), flexible thinking (flexibility), evaluative thinking (evaluative), detailed thinking, and fluent thinking (fluent). Integration *ESD* applied to the original thinking indicator, the strongest indicator, with a high category, reached an N-gain of 0.910. Integration *ESD* applied to the flexibility indicator, the weakest indicator, achieved an N-gain value of 0.108 in the low category.

Furthermore, problem-solving skills are also a significant focus in ESD integration. Through a contextual problem-based learning approach, learners are trained to identify, analyze, and develop sustainable solutions to real problems in their environment. In the research of (Azakia & Gunansyah, 2025) and (Pradipta & Hariyono, 2021)), the problem-solving indicators used according to Polya are four: understanding the problem, planning solutions, implementing plans, and reflecting. The integration of *ESD* in research (Azakia & Gunansyah, 2025) was applied to these four indicators, but the strongest integration was observed in the implementation indicators. In this indicator, students design promotive, preventive, curative, and rehabilitative solutions related to climate change that can trigger real student actions. Integration *ESD*: The weakest indicator is understanding the problem, because it only assesses conceptual understanding; there is no awareness of values or sustainability actions. Research by (Pradipta & Hariyono, 2021) resulted in the integration of *ESD*. The strongest indicators are understanding the problem and planning solutions, with N-gain scores of 0.87 and 1.00, respectively. In these two indicators, students identify societal problems and plan solutions. Integration *ESD*: The weakest indicators in this study are those related to implementing plans and reflecting, with N-gain values of 0.39 and 0.47, respectively. Existing research consistently shows improved students' problem-solving skills after applying the ESD approach.

In addition, the implementation of ESD also emphasize strengthening sustainability awareness as part of 21st-century skills. Existing research shows that the application of *ESD* in learning effectively fosters students' awareness of sustainability. Research (Muflikhah, 2023) using the three leading indicators of sustainability awareness as explained by Hassan et al. (2010), including emotional awareness, behavioral & attitude awareness, and sustainability practice awareness. Integration *ESD* In this study, there are three aspects, and the strongest integration is in the indicators of Behavioral & Attitude Awareness. Research (Laela et al., 2024) using three sustainability awareness indicators, including knowledge, attitudes, and behaviors, adapted from the UNESCO framework (2012) and research (Hudha et al., 2021), which emphasizes that sustainability awareness must include cognitive, affective, and conative (action) dimensions. *ESD* is integrated into the three sustainability awareness indicators, with the strongest integration in the behavior indicator. In research (El Magheest & Suryanti, 2025), using three indicators of sustainability awareness, including knowledge (*knowledge*), attitude (*attitude*), and behavior (*behavior*), which is in line with the three main dimensions of the UNESCO framework (2017). *ESD* is integrated into the three sustainability awareness indicators, and its integration is most powerful in the behavioral indicators (*behavior*). Both studies show that integrating sustainability values into science learning can increase students' understanding of the importance of environmentally friendly behavior and of sustaining life.

Through learning activities contextualized around environmental issues, students become more aware of the impact of human actions on the earth and are encouraged to actively participate in preserving it.

Science literacy becomes a skill developed along with ESD integration. Several studies show that ESD integration positively affects students' science literacy. Research by (Kiswanda et al., 2022) using science literacy indicators, which include explaining phenomena, designing investigations, interpreting data, and applying science concepts with reference to the science literacy framework developed by PISA (OECD, 2018) and Bybee (1997), which emphasizes the ability of learners to understand, interpret, and use scientific knowledge in real-life contexts. Application *ESD* integrated into the science literacy indicators, the most prominent is the application of science concepts. From research (Dieni et al., 2022), (Kiswanda et al., 2022) and (Sari et al., 2024) it emphasizes the application of ESD-based learning approaches oriented towards environmental and sustainability issues. ESD-based learning has been proven to strengthen students' ability to interpret scientific phenomena, use evidence to support arguments, and evaluate environmental problems through a scientific approach. Science learning integrated with ESD encourages students to think scientifically, critically, and reflexively in the face of sustainability issues, so that science literacy develops not only as knowledge, but also as scientific thinking and acting skills relevant to the challenges of the 21st century.

Finally, environmental literacy also emerged as an essential competency resulting from the application of ESD in science learning. Research (Zulfah et al., 2024) using four key indicators of environmental literacy adapted from Febriasari & Supriatna (2017) and the UNESCO framework (2012), including knowledge (*knowledge*), attitude (*attitude*), cognitive skills (*cognitive skills*), and behavior (*behavior*). Integration *ESD* is strongest in attitude indicators, because at this stage, students build ecological values and responsibilities that are at the core of education for sustainable development. The results of the study show that students become more critical in assessing the impact of human activities on the environment and can formulate scientifically responsible actions. Learning that emphasizes contextual problem-solving encourages students to understand the relationship between science concepts and real life, while fostering concern for environmental sustainability.

Effective learning model in integrating ESD concepts to improve 21st century skills in science learning

Effective learning models in integrating ESD concepts to improve 21st century skills in science learning include Problem Based Learning (PBL), Project Based Learning (PjBL), Search, Solve, Create, and Share (SSCS), Predict–Observe–Explain (POE), and (Read, Answer, Discuss, Explain, Create) RADEC. Some of the learning models often used in ESD in science learning to improve 21st century skills learning are shown in Table 3.

Table 3. Results of Analysis and Review of Articles Based on Learning Models

21st Century Skills	Learning Model
Critical Thinking	PBL ((Nurasiah, 2025), (Amsal et al., 2025))
	PjBL ((Muntamah et al., 2024), (Vilmala et al., 2025))
	RADEC (Lestari & Rahmawati, 2022)
	POE (F.N.U. Fatimah et al., 2023)
	SSCS (Afwah et al., 2024)
Creative Thinking	PBL (Rohmawati et al., 2023)
	RADEC (Lestari & Rahmawati, 2022)
Problem solving	PBL (Azakia & Gunansyah, 2025), (Pratiwi & Widowati, 2024)
Sustainability Awareness	PBL (Muflikhah, 2023)
	PjBL (Laela et al., 2024)
Science Literacy	-
Environmental Literacy	PBL (Zulfah et al., 2024)

The table shows the relationship between 21st-century skills and the learning models used in various studies. Critical thinking is developed through multiple models, such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), RADEC, POE, and SSCS, indicating that these skills require a varied learning approach and emphasize deep thinking. Creative thinking skills are also supported by the PBL and RADEC models, which encourage students to generate new ideas and innovative solutions. Problem-solving skills, sustainability awareness, and environmental literacy are primarily developed through PBL, and, in the context of sustainability, are also strengthened through PjBL, because these two models provide opportunities for students to learn through real situations. Meanwhile, in science literacy, no learning model is mentioned explicitly in the summarized study. Overall, this table shows that PBL is the dominant model for developing various 21st-century skills, especially those related to thinking processes and problem-solving. Distribution of the learning models often used in ESD in science learning to improve 21st century skills learning are shown in Figure 3.

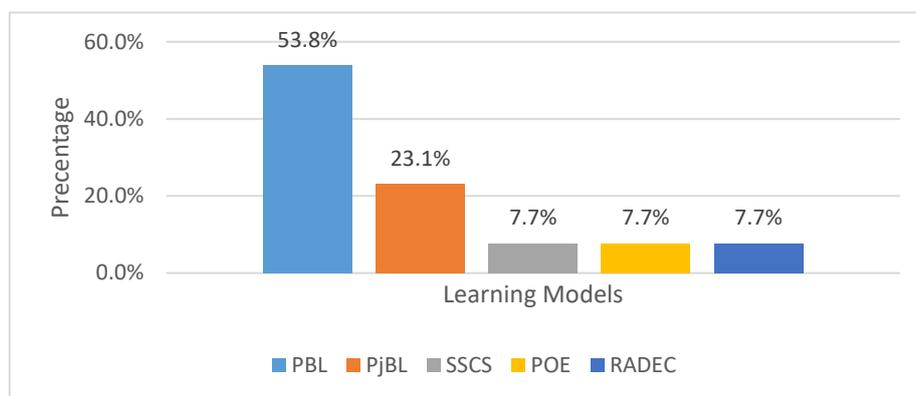


Figure 3. Distribution of Learning Models

Based on the Learning Model Distribution diagram, the most widely used learning model is Problem-Based Learning (PBL) with a proportion of 53.8% ($n=7$). This model shows that problem-based learning is considered most effective in the context of Education for Sustainable Development (ESD) because it trains learners to think critically, solve real problems, and foster sustainability awareness through active involvement in the learning process. Furthermore, the Project-Based Learning (PjBL) model ranks second, with a proportion of 23.1% ($n=3$). This model emphasizes collaboration, creativity, and the application of scientific concepts to projects focused on sustainability solutions. PjBL has proven to be effective in developing 21st-century skills such as communication, collaboration, and critical thinking. Some of the other learning models are SSCS (Search, Solve, Create, and Share), Predict–Observe–Explain (POE), and RADEC, each with a proportion of 7.7% ($n=1$). Although less frequent, the model still plays an essential role in supporting ESD-based contextual learning, for example, by training learners to conduct scientific inquiry, relate theory to practice, and share findings with their learning environment.

In improving critical thinking skills, some early research has not explained in detail the most appropriate learning model to integrate with ESD. Research conducted by (Nurasiah, 2025) and (Amsal et al., 2025), shows that the Problem-Based Learning (PBL) model with ESD integration has proven to be effective in improving critical thinking skills. This model encourages students to solve contextual problems related to environmental issues, thereby fostering the ability to analyze, evaluate, and infer logically. Meanwhile, research (Muntamah et al., 2024) and (Vilmala et al., 2025) found that the Project-Based Learning (PjBL) model integrated with ESD also improves critical thinking skills through real project activities, such as exploration, innovation, and cooperation among students. In addition, the research (Lestari & Rahmawati, 2022) revealed that the ESD-oriented RADEC (Read, Answer, Discuss,

Explain, Create) model is effective in fostering critical thinking skills by providing space for students to read about sustainability issues, discuss them, and develop creative solutions. Research (F.N.U. Fatimah et al., 2023) also shows that the Predict–Observe–Explain (POE) model with ESD integration is effective in training critical thinking skills in electrical concept materials, as it requires students to think analytically to predict and explain scientific phenomena. Next (Afwah et al., 2024) proving that the ESD-based SSCS (Search, Solve, Create, Share) model can improve critical thinking skills through systematic stages in solving environmental problems scientifically. Although most studies show an increase in critical thinking skills in the medium to high category, some limitations are still found, such as the absence of effectiveness tests with a balanced control group, limited sample counts, and new applications limited to product trials. A combination of learning models, such as PBL and PjBL with ESD-based digital media support, such as *E-Module*, *e-LKPD*, or *virtual field trip*, is also considered to have the potential to further optimize the development of critical thinking and sustainability awareness of students.

Research on improving creative thinking skills (Rohmawati et al., 2023) using a Problem-Based Learning (PBL) model integrated with ESD shows that implementing *PBL-ESD* is effective in enhancing students' creative thinking skills through problem-based learning activities associated with environmental issues. This model requires students to analyze sustainability problems, propose alternative solutions, and evaluate their impact on daily life. Through this process, students practice divergent and flexible thinking in associating science concepts with environmental conservation efforts. Thus, the PBL model is integrated with *ESD*, encouraging students to develop original and innovative ideas in finding scientific solutions to global problems. Meanwhile, research (Lestari & Rahmawati, 2022) using the RADEC (Read, Answer, Discuss, Explain, Create) model integrated with ESD shows that the RADEC Integrated ESD learning model is effective in fostering creative thinking skills through systematic and reflective learning stages. Phase *read* and *Answer*: Lead students to understand sustainability issues. Discuss and explain: Practice open and collaborative thinking skills while creating. It is the main stage for fostering creative thinking among students to generate new ideas for solving environmental problems. However, the increase in the study is still in the medium category. These findings reinforce the view that contextual and sustainability-oriented science learning not only improves mastery of scientific concepts but also fosters creative thinking skills in developing new ideas relevant to global challenges.

To improve your problem-solving skills, most studies apply the *Problem Based Learning* (PBL) model integrated with ESD, as in research (Pratiwi & Widowati, 2024) and (Azakia & Gunansyah, 2025). The results of the two studies show that the application of the PBL learning model, integrated with ESD, is effective in improving students' problem-solving skills. Through problem-based learning, students are trained to systematically identify problems, analyze their causes, and design rational and sustainable solutions. Integration of *ESD* deep *PBL* also helps students understand the relevance of science to sustainability issues, so that the solutions they produce are not only theoretical but also applicable to environmental problems. In addition, research developed by (Pradipta & Hariyono, 2021) and (Najwa, 2023) using a learning tool-based development approach, *ESD*, such as e-modules and contextual teaching materials, also contributes to improved problem-solving skills. Development of learning tools *ESD* provides opportunities for students to actively learn, explore sustainability issues, and relate them to the scientific concepts studied. Through these tools, students are trained to identify problems, evaluate information, and devise relevant and sustainability-oriented alternative solutions. This approach has been shown to improve high-level thinking skills, including problem-solving, although most research remains at the trial stage. Overall, the results of the study show that PBL and the development of ESD-based learning tools are equally effective in improving students' problem-solving skills. Oriented learning in *ESD* provides a more meaningful learning experience because it puts students in active roles as

problem solvers in real-life contexts. Although the resulting improvement in problem-solving skills remains moderate, these findings reinforce that integrating ESD into science learning plays an essential role in developing scientific, systematic, and reflective ways of thinking that underpin problem-solving skills.

As for increasing awareness of research sustainability (Muflikhah, 2023) Apply the model *Problem-Based Learning (PBL)* integrated with the *ESD*. Through problem-based learning, learners are trained to analyze real environmental issues and develop sustainability-oriented solutions. The process of problem identification, investigation, and reflection encourages students to think critically while fostering concern for the relationship between human activities and ecosystem balance. Integration *PBL* with *ESD* It is proven to increase students' sustainability awareness of their responsibility in preserving the environment. Meanwhile, research (Laela et al., 2024) applies the model *Project-Based Learning (PjBL)* *ESD*-based. Through project activities oriented towards real solutions to sustainability problems, students play an active role in designing and implementing projects that emphasize ecological responsibility. Stages in projects such as planning, implementation, and evaluation help students understand that sustainability does not depend solely on scientific knowledge but also on concrete actions that benefit the environment. Meanwhile, research (Hikmah & Suratmi, 2025) and (El Magheest & Suryanti, 2025) has not used a specific learning model, but emphasizes the application of the *ESD* approach directly in the learning process.

Furthermore, to improve the literacy of the research environment (Zulfah et al., 2024) shows that the integration of *Problem-Based Learning (PBL)* with *ESD* is effective in improving students' environmental literacy skills. Through problem-based learning, students are trained to identify and analyze real environmental issues, then seek sustainability-oriented scientific solutions. The stages in *PBL*, such as problem understanding, information gathering, and reflection on results, help students develop scientific thinking skills and ecological awareness simultaneously.

Overall, these results show that research on *ESD* most often applies problem-based and project-based learning models, as both integrate critical thinking, collaboration, and sustainability awareness skills in accordance with the Sustainable Development Goals (SDGs). Research on Education for Sustainable Development (*ESD*) shows that learning models such as *PBL*, *POE*, *PjBL*, *RADEC*, and *SSCS* are effective in improving students' 21st-century skills. Overall, *ESD*-based learning models such as *PBL*, *PjBL*, *POE*, *RADEC*, and *SSCS* support the achievement of the Sustainable Development Goals (SDGs) by strengthening critical thinking, collaboration, and environmental awareness through relevant, contextual learning.

The learning material topics that can be used to integrate ESD in science learning

Material topics that can be used to integrate *ESD* into science learning include environmental sustainability, covering climate change, ecosystems, biodiversity, environmental pollution, environmental issues, environmental change, crop cultivation, global warming, and bioplastics. The dominance of this topic reflects strong attention to sustainability, ecosystem balance, and the impact of human activities on the environment. Furthermore, the issues of Energy and Force include energy and matter, the laws of thermodynamics, rotational dynamics, the pressure of liquids and fluids, and static electricity. The intense focus on this topic can be attributed to the urgency of understanding energy in the context of efficiency, conservation, and the transition to sustainable energy sources. The topic of Earth Systems and the Environment include material on water cycles and ecology. This topic remains relevant because it is directly related to natural phenomena and the environmental cycles that support life. The topic of Structure and Function of Living Beings consists of material on the digestive system, and the topic of Matter and Its Properties consists of Element, Compound, and Mixed material. Meanwhile, the topic of Scientific Skills and Science includes Measurement and Science materials, which are essential for training science process skills and understanding

cross-disciplinary concepts. Result the learning material topics that can be used to integrate ESD in science learning on Table 4.

Table 4. Results of Analysis and Review of Articles Based on Learning Topics

Topic	Sum	Reference
Environment and Sustainability	13	(Azakia & Gunansyah, 2025), (Amelia et al., 2025), (Najwa, 2023), (Damayanti et al., 2025), (Afwah et al., 2024), (Lestari & Rahmawati, 2022), (El Magheest & Suryanti, 2025), (Amsal et al., 2025), (Muflikhah, 2023), (Jamaludin, 2022), (I. Fatimah et al., 2022), (Sari et al., 2024), (Kiswanda et al., 2022)
Energy and Force	10	(Nurasiah, 2025), (El Magheest & Suryanti, 2025), (Hikmah & Suratmi, 2025), (Zulfah et al., 2024), (Dieni et al., 2022), (Kiswanda et al., 2022), (Rohmawati et al., 2023), (Pradipta & Hariyono, 2021), (Vilmala et al., 2025), (F.N.U. Fatimah et al., 2023)
Earth System and Environment	2	(El Magheest & Suryanti, 2025), (Laela et al., 2024)
Structure and Function of Living Beings	1	(Novianti et al., 2023)
Material and Its Properties	1	(Pratiwi & Widowati, 2024)
IPAS	2	(Muntamah et al., 2024), (Laela et al., 2024)

The table illustrates the distribution of topics studied in various studies. The topic of Environment and Sustainability was the most dominant, with 13 studies, showing that ecological issues, sustainability, and environmental education received the most attention in the learning study. Furthermore, Energy and Force rank second with 10 studies, indicating that the concepts of energy and physical interaction are also widely explored. Meanwhile, the topics of Earth and Environmental Systems and IPAS appeared in two studies, so the theme is starting to develop, but has not been studied extensively. The topic of the Structure and Function of Living Beings and Their Matter and Nature were found only in one study, indicating that research in this field remains limited. Overall, this table shows that this study focuses more on sustainability and energy issues than on other science topics. Distribution of learning material topics that can be used to integrate ESD in science learning on Figure 4.

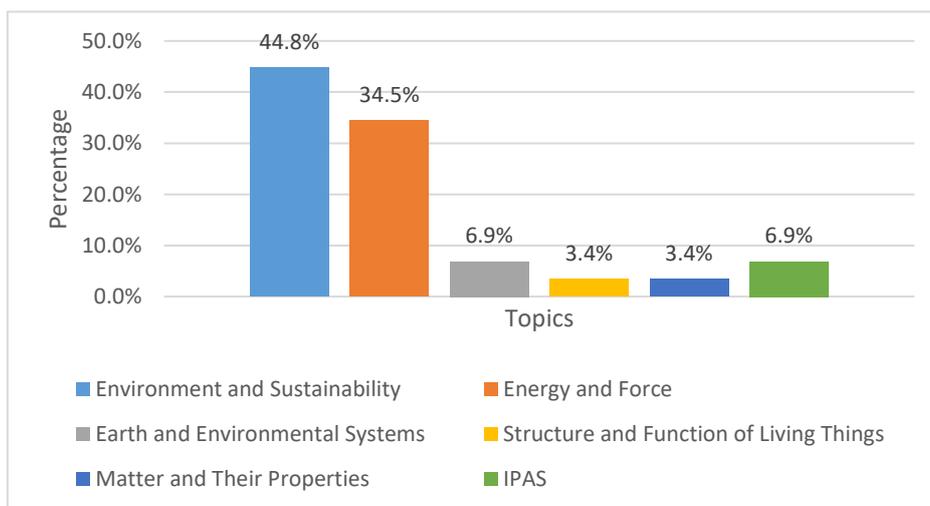


Figure 4. Distribution of Learning Topics

Based on the Learning Topic Distribution chart above, the topic of Environment and Sustainability has the highest proportion at 44.8%, indicating that most research or learning

activities focus on this theme. This topic includes materials on Climate Change (n=3), Ecosystems (n=3), Biodiversity (n=1), Environmental Pollution (n=1), Environmental Issues (n=1), Environmental Change (n=1), Plant Cultivation (n=1), and Bioplastics (n=1). Furthermore, the topic of Energy and Force ranks second, with a proportion of 34.5%. Materials included in this category include Energy (n=5), Law of Thermodynamics (n=1), Rotational Dynamics (n=1), Pressure of Liquids (n=1), Fluids (n=1), and Static Electricity (n=1). The topic of Earth and Environmental Systems accounted for 6.9% of the total, consisting of Water Cycle (n=1) and Ecology (n=1) material. Although the percentage is small, this topic remains relevant because it directly relates to natural phenomena and the environmental cycles that support life. The issues of Structure and Function of Living Beings and Matter and Their Properties each have a proportion of 3.4%, with the material of the Digestive System (n=1) and Elements, Compounds, and Mixtures (n=1). Meanwhile, the topic of science also contributed 6.9%, consisting of science materials (n=2), which are essential for training science process skills and understanding cross-disciplinary concepts. Overall, this diagram shows that the topics of Environment and Sustainability and Energy and Force are the main focus of learning. Both reflect efforts to instill awareness of global issues such as climate change, energy crisis, and sustainable development, in line with the direction of modern science education that emphasizes ESD

Science learning topics relevant to application *ESD*, covering Environment and Sustainability with the highest proportion of 44.8%, followed by Energy and Force at 34.5%. These two topics are the primary focus of science-based research and ESD learning because they require scientific understanding alongside sustainability awareness. Environment and Sustainability topics cover a wide range of materials, including climate change, ecosystems, biodiversity, environmental pollution, environmental issues, environmental change, crop cultivation, and bioplastics. These materials focus on understanding the relationship between human activities and the balance of nature and encourage students to be concerned about environmental sustainability. Some studies show that integrating ESD can improve students' critical thinking skills, sustainability awareness, and environmental literacy. For example, on climate change material, research by (Damayanti et al., 2025) and (Amelia et al., 2025) showed an improvement in students' critical thinking skills, while research by (Azakia & Gunansyah, 2025) resulting in improved problem-solving skills. Meanwhile, in the ecosystem material, research by (Muflikhah, 2023) and (El Magheest & Suryanti, 2025) demonstrate increased sustainability awareness, and research (Amsal et al., 2025) shows an increase in critical thinking skills. Biodiversity material related research (Laela et al., 2024) increase students' sustainability awareness, while research on critical thinking (Jamaludin, 2022) Improve these skills. Likewise in environmental pollution materials, research (Afwah et al., 2024) students' critical thinking skills improve. Other materials, such as crop cultivation, bioplastics, and environmental issues, have also been examined in some studies. However, they remain limited and require further development to assess their effectiveness in the context of *ESD*. Furthermore, the topic of Energy and Force, which has a proportion of 34.5%, is also very relevant to the application of *ESD* because it discusses energy efficiency, resource conservation, and sustainable energy utilization. This topic includes energy and matter, the laws of thermodynamics, rotational dynamics, the pressure of liquids and fluids, and static electricity. Among these materials, energy is the most widely used in research, namely by (Nurasiah, 2025), (El Magheest & Suryanti, 2025), (Hikmah & Suratmi, 2025), (Zulfah et al., 2024) and (Dieni et al., 2022). Research (Dieni et al., 2022) and (Zulfah et al., 2024) show that the implementation of *ESD* in energy learning can improve science and environmental literacy and foster concern for the use of sustainable energy. Research (El Magheest & Suryanti, 2025) and (Hikmah & Suratmi, 2025) also found that learning with an ESD orientation can increase students' sustainability awareness, while research (Nurasiah, 2025) indicates that integrating ESD into learning can improve students' critical thinking skills. In addition, the research

(Vilmala et al., 2025) indicates that fluid matter also increases critical thinking skills. Other topics, such as the Earth System and the Environment, the Structure and Function of Living Things, and Matter and Its Properties, are also related to *ESD*, although the proportions are small. Water cycle and ecology material on the topic of Earth System and Environment, as well as digestive system on the Structure and Function of Living Things, show potential relevance to the development of environmental awareness. Research (Novianti et al., 2023) for example, shows that integrating *ESD* into science learning, specifically on the digestive system, is effective in improving students' critical thinking skills. Meanwhile, topics such as elements, compounds, and mixtures, as well as IPAS that appear in small portions, also play a role in training scientific skills and cross-disciplinary understanding. However, they have not been widely researched in the context of *ESD*. The results of the analysis show that the topics of Environment and Sustainability and Energy & Force are the most relevant themes in the *ESD* in science learning. These two topics not only strengthen mastery of scientific concepts and critical thinking skills but also foster awareness of sustainability and responsibility towards the environment. This is in line with UNESCO(2017) view that *ESD*-based learning must help learners develop a deep scientific understanding and the ability to act responsibly in the face of environmental challenges and to support sustainable development in the future.

The overview of the implementation of *ESD* in science learning

Based on the results of the literature review, the implementation of *ESD* in science learning is relevant to the PBL, PjBL, POE, SSCS, and RADEC models, with *ESD* integration applied across all learning syntaxes or to several learning syntaxes. Result the overview of the implementation of *ESD* in science learning on Table 5.

Table 5. Results of Analysis and Review of Articles Based on *ESD* Integration

Type	Forms of Integration	Reference
PBL	In all PBL syntax, from orientation to reflection, the strongest <i>ESD</i> integration is in the syntax of developing and presenting the work.	(Azakia & Gunansyah, 2025), (Nurasiah, 2025)
	Integrate <i>ESD</i> across the entire PBL syntax, but the most powerful <i>ESD</i> integration is in the investigation syntax.	(Rohmawati et al., 2023) (Muflikhah, 2023) (Zulfah et al., 2024)
PjBL	The most powerful <i>ESD</i> integration is in the syntax of project execution and evaluating experience	(Laela et al., 2024)
SSCS	Integrated on all SSCS syntax: Search-Solve-Create-Share, but at the most powerful create stage.	(Afwah et al., 2024)
POE	Integrated at all stages of <i>POE: Predict-Observe-Explain</i> , but at the most powerful observe stage	(F.N.U. Fatimah et al., 2023)
RADEC	<i>ESD</i> integration appears in all RADEC (<i>Read, Answer, Discuss, Explain, Create</i>) syntax, but the strongest integration is at the create stage.	(Lestari & Rahmawati, 2022)

Conceptually, the success of science learning in developing 21st-century skills is primarily determined by the right learning model and the selection of contextual material topics aligned with sustainability principles. Integration *ESD* not only strengthens students' cognitive aspects but also develops their affective and psychomotor aspects to address global challenges. Implementation of *ESD* in science learning describes a systematic effort to integrate sustainability values into the science learning process that is contextual and oriented towards 21st-century skill development. In research (Azakia & Gunansyah, 2025) and (Nurasiah, 2025)

integration of *ESD* deep *PBL* is carried out on the entire learning syntax, from problem orientation to reflection. However, the integration of *ESD* is the most powerful syntax in developing and presenting the results of the work because students create promotive, preventive, curative, and rehabilitative solutions to climate change issues by combining cognitive, affective, and psychomotor dimensions of *ESD* realistically and apply the concept of science to renewable energy issues to design applicable and sustainable solutions. At this stage, it also represents three dimensions *ESD* cognitive, affective and psychomotor. Research (Rohmawati et al., 2023) and (Muflikhah, 2023) and (Zulfah et al., 2024) also integrate *ESD* into the entire *PBL*, but *ESD* is most powerful in the investigation's syntax. At this stage, students investigate through the *LKPD*, which explicitly asks them to apply the principles of *ESD* to analyze environmental problems, assess environmental impacts, and examine sustainable solutions related to the application of rotation dynamics & environment, and students really analyze energy issues from the aspect of environmental sustainability. Research (Laela et al., 2024) directly applies *ESD* through the model *Project-Based Learning (PjBL)* in social studies learning. Implementation of *ESD* is realized through environmental projects that invite students to understand sustainability issues and develop sustainability consciousness (sustainable knowledge, attitudes, and behaviours)—integration of *ESD*. The most powerful are in the syntax of project execution and evaluating experience. At this stage, students take concrete actions, analyze environmental issues directly, and apply sustainability principles in the project process. In research (Afwa et al., 2024) *ESD* is integrated into all *SSCS* (Search, Solve, Create, Share) syntaxes. Still, in Create step, it is the most powerful, as students create projects based on sustainability principles and real environmental action. Research by (F.N.U. Fatimah et al., 2023) shows that *ESD* is integrated across all levels of *POE* (Predict, Observe, Explain), but at the observation stage, it is most powerful because students observe and test natural phenomena directly in real-life contexts. In research (Lestari & Rahmawati, 2022) *ESD* integration appears in all *RADEC* syntax (*Read, Answer, Discuss, Explain, Create*). However, the strongest integration is at the Create stage. At this stage, students are asked to produce fundamental ideas, actions, or products that are oriented towards environmental solutions and sustainable living practices.

Based on the results of a study of 25 research articles for the 2020–August 2025 period, the implementation of *ESD* is carried out through the development of learning tools such as *e-modules*, *LKPDs*, digital media, and virtual *field trips* that contain real environmental issues, such as renewable energy, climate change, and environmental pollution. *ESD*-based learning generally uses *the Problem-Based Learning (PBL)* and *Project-Based Learning (PjBL)* models, as both place students as active, critical, and reflective learning centres in analyzing and solving sustainability problems. The *PBL* model encourages students to scientifically identify and solve environmental issues, while the *PjBL* provides space for them to design real, solution-oriented projects. Several other models, such as *Predict–Observe–Explain (POE)*, *RADEC*, and *SSCS*, are also implemented to strengthen students' critical and creative thinking skills. The results of the research synthesis show that *ESD* integration plays an essential role in improving critical thinking skills, problem-solving, creative thinking, and environmental sustainability awareness. The most dominant skill developed is critical thinking, with the most frequently used topics relating to the environment and sustainability, as well as energy and force. The most widely applied learning models are *Problem-Based Learning (PBL)* and *Project-Based Learning (PjBL)*, both of which encourage students to actively participate in producing real solutions to sustainability problems. In addition, *ESD* also positively affects science literacy, especially in the ability to explain phenomena, interpret data, and apply scientific concepts to daily life. The implementation of *ESD* also increases sustainability awareness, which includes knowledge, attitudes, and behaviors, with the finding that behavioral aspects are the most powerful dimension developed through learning that is contextualized with environmental issues. Overall, *ESD*-based science learning not only emphasizes mastery of scientific

concepts, but also forms students who are critical, creative, and care about the environment, so that they are able to contribute to realizing sustainable development.

CONCLUSION

Based on the results of a systematic literature review of 25 articles on the application of *ESD* in science learning in Indonesia in the period 2020–August 26, 2025, it can be concluded that the application of *ESD* plays an important role in building students' 21st century competencies, especially critical thinking skills and sustainability awareness. The studies analyzed show that *ESD*-based learning is still dominated by the development of learning tools such as e-modules, LKPDs, and sustainability-oriented digital teaching materials, while research examining its effectiveness and long-term impact is still limited.

The most used learning models are Problem-Based Learning (PBL) and Project-Based Learning (PjBL), as they both train students' critical thinking, creative thinking, and social responsibility skills through real problem-solving. Topics most often integrated with *ESD* include environment and sustainability, as well as energy and forces relevant to efforts to achieve the Sustainable Development Goals (SDGs). The results of the study also show that although the awareness of sustainability and critical thinking skills of students in general is still relatively moderate to low, as shown in the study (Nurasiah, 2025) and (Amsal et al., 2025), *ESD* integration has the potential to be a solution to overcome this. Strengthening sustainability values through contextual, problem-based and project-based science learning can improve 21st-century skills. Thus, the integration of *ESD* into science learning needs to continue to be developed through effective learning strategies to improve students' 21st-century skills.

RECOMMENDATION

Based on the results of the analysis of 25 articles examining the application of Education for Sustainable Development (*ESD*) in science learning, several suggestions can be made for future research. First, subsequent research needs to use a more robust research design by including a control group and a larger sample size. This is important so that the research results are more accurate and can describe the influence of *ESD* more clearly. In addition, most research focuses on critical thinking skills, so in the future, it is necessary to develop other 21st-century skills, such as collaboration, cooperation, and communication. In addition, future research needs to expand the topic of science learning associated with *ESD*. Topics such as biotechnology, waste management, and environmental health are relevant to sustainability issues. Many studies measure learning outcomes only over short periods, so long-term research is needed to assess the impact of *ESD* on an ongoing basis. Overall, a more varied, planned, and contextual strategy is required for integrating *ESD* into science learning to help students truly develop 21st-century skills and build sustainability awareness.

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Conflict of Interest Statement

Authors state no conflict of interest.

Data Availability

The data that support the findings of this study are available on request from the corresponding author. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

REFERENCES

- Afwa, S. R., Suryawati, E., & Yennita, Y. (2024). Penerapan Model SSCS Berpendekatan ESD (Education Sustainable Development) Untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik Pada Materi Pencemaran Lingkungan Di SMP. *BEST Journal (Biology Education, Sains and Technology)*, 7(2), 442–448.
- Alissa, V. (2022). Kesadaran Peserta Didik Dalam Penerapan Green School Untuk Mendukung ESD (Education for Sustainable Development). *EduTeach: Jurnal Edukasi Dan Teknologi Pembelajaran*, 3(2), 51–60.
- Amelia, I., Saefullah, A., & Antarnusa, G. (2025). Pengembangan Pengembangan E-Modul Fisika Terintegrasi Education For Sustainable Development (ESD) Untuk Memfasilitasi Kemampuan Berpikir Kritis Siswa. *Jurnal Pendidikan Fisika Undiksha*, 15(1), 1–12.
- Amsal, T. A. W., Haerani, R. P. R., & Suhartini, E. (2025). Pengaruh Model Pembelajaran PBL Berbasis ESD Dalam Meningkatkan Kompetensi Berpikir Kritis Siswa Pada Materi Ekosistem Di Kelas V. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, 10(02), 271–279.
- Azakia, A. A., & Gunansyah, G. (2025). Desain pembelajaran ipas berbasis problem based learning dan esd untuk meningkatkan keterampilan pemecahan masalah siswa sd. *Jurnal Penelitian Pendidikan Guru Sekolah Dasar*, 13(3), 787–801.
- Booth, A., Martyn-St James, M., Clowes, M., & Sutton, A. (2021). *Systematic approaches to a successful literature review*.
- Damayanti, R., Suratmi, S., & Raharjo, M. (2025). Development of ESD-Oriented Google Sites Learning Media to Improve Critical Thinking Skills of Elementary School Students. *Jurnal Ilmu Pendidikan (JIP) STKIP Kusuma Negara*, 17(1), 17–32.
- Dieni, W. E. F., Hernani, H., & Kaniawati, I. (2022). Applying the education for sustainable development approach to energy instruction design for encouraging scientific literacy of junior high school students. *Jurnal Pendidikan MIPA*, 23(2), 670–680.
- El Magheest, A. P., & Suryanti, S. (2025). Implementasi education for sustainable development dan pencapaian kesadaran berkelanjutan dalam pembelajaran ipa di SD alam. *Jurnal Penelitian Pendidikan Guru Sekolah Dasar*, 13(1), 267–281.
- Fatimah, F., & Haryati, T. (2024). Implementasi Kegiatan Proyek Penguatan Profil Belajar Pancasila (P5) Dalam Menumbuhkan Budaya Mutu Di MTs. Negeri Batang. *Paedagogy: Jurnal Ilmu Pendidikan Dan Psikologi*, 4(2), 98–104.
- Fatimah, F. N. U., Siswanto, J., Nuroso, H., & Hayat, M. S. (2023). Implementation of the education for sustainable development (ESD) based predict, observe, and explain (POE) learning module to improve critical thinking skills. *Practice of The Science of Teaching Journal: Jurnal Praktisi Pendidikan*, 2(2), 52–63.
- Fatimah, I., Hamdu, G., & Hidayat, S. (2022). Pengembangan Elektronik-Lembar Kerja Peserta Didik Virtual Field Trip Berbasis Education for Sustainable Development di SD. *ATTADIB*, 6(1).
- Hikmah, P. D., & Suratmi, S. (2025). Pengembangan Modul Ajar Berorientasi ESD Pada Materi Hemat Energi Di Kelas VI Sekolah Dasar. *Autentik: Jurnal Pengembangan Pendidikan Dasar*, 9(2), 343–360.
- Jamaludin, Z. Z. (2022). E-Modul keanekaragaman hayati berbasis education for sustainable development untuk mendukung implementasi Flipped Learning. *Jurnal Cakrawala Pendas*, 8(4), 1550–1570.

- Kementerian Pendidikan dan Kebudayaan Republik Indonesia. (2017). Pendidikan untuk pembangunan berkelanjutan di Indonesia: Implementasi dan kisah sukses. Jakarta: Kementerian Pendidikan dan Kebudayaan.
- Kiswanda, V., Aswirna, P., & Nurhasnah, N. (2022). Pengembangan E-Modul fisika berbasis STEM dengan prinsip pembangunan berkelanjutan terhadap literasi SAINS siswa kelas XI. *Journal Cerdas Mahasiswa*, 4(1), 62–75.
- Laela, F. N., Khoiri, A., & Sugiyanto, B. (2024). Efektivitas Penerapan Education for Sustainable Development Melalui Pembelajaran Berbasis Proyek Terhadap Sustainability Consciousness Siswa Kelas 4 MI Ma'arif Kliwonan Wonosobo Pada Mata Pelajaran IPAS Tahun Pelajaran 2023/2024. *Jurnal Intelek Dan Cendekiawan Nusantara*, 1(2), 2968–2972.
- Lestari, H., & Rahmawati, I. (2022). Pendidikan Pembangunan Berkelanjutan Dimensi Pelestarian Lingkungan Melalui Model Pembelajaran RADEC Pada Pembelajaran IPA Di Sekolah Dasar. *Jurnal Kajian Islam Modern*, 8(1), 1–13.
- Mardhiyah, R. H., Aldriani, S. N. F., Chitta, F., & Zulfikar, M. R. (2021). Pentingnya keterampilan belajar di abad 21 sebagai tuntutan dalam pengembangan sumber daya manusia. *Lectura: Jurnal Pendidikan*, 12(1), 29–40.
- Maulani, M., Kurniawan, D. A., & Jumiarti, H. (2021). Identifikasi kemampuan analisis siswa dengan menerapkan model pembelajaran berpusat pada guru (Teacher Center Learning) pada mata pelajaran fisika di SMA N 1 Lubuk Sikaping. *SENRIABDI*, 143–150.
- Muflikhah, I. K. (2023). Implementasi PBL berorientasi ESD dalam meningkatkan literasi dan sustainable awareness peserta didik madrasah ibtidaiyah Soko Pekalongan. *Akselerasi: Jurnal Pendidikan Guru MI*, 4(2), 89–99.
- Muntamah, M., Roshayanti, F., & Hayat, M. S. (2024). Keterampilan Berpikir Kritis Siswa SMK Pada Pembelajaran Projek IPAS Berorientasi ESD dan Pendekatan STEAM. *Jurnal Penelitian Pembelajaran Fisika*, 15(1), 80–87.
- Najwa, H. A. (2023). Development of E-Module Integrated with Education for Sustainable Development (ESD) on Enviromental Change Material. *Jurnal Penelitian Pendidikan IPA*, 9(12), 12130–12138.
- Novianti, R., Suhendar, S., & Ratnasari, J. (2023). Pengembangan e-module berbasis education for sustainable development untuk melatih kompetensi berpikir kritis pada siswa. *Bioscientist: Jurnal Ilmiah Biologi*, 11(1), 639–655.
- Nurasiah, S. (2025). Pengaruh E-Modul Fisika Terintegrasi ESD pada Materi Energi Terbarukan terhadap Kemampuan Berpikir Kritis Siswa. *Jurnal Pendidikan Fisika Undiksha*, 15(1), 24–35.
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., & Moher, D. (2021). Updating guidance for reporting systematic reviews: development of the PRISMA 2020 statement. *Journal of Clinical Epidemiology*, 134, 103–112.
- Pradipta, D. D., & Hariyono, E. (2021). The effectiveness of science learning tools based on education sustainable development (ESD) to improve problem-solving skills. *IJORER: International Journal of Recent Educational Research*, 2(3), 342–353.
- Pratiwi, R. I. A., & Widowati, A. (2024). Development of a Science e-Book by Exploring Traditional Food Within a PBL-ESD Framework to Foster Students' Problem-Solving Skills. *Jurnal Pendidikan MIPA*, 25(3), 1604–1617.
- Purnamasari, S., & Hanifah, A. N. (2021). Education for Sustainable Development (ESD) dalam pembelajaran IPA. *Jurnal Kajian Pendidikan IPA*, 1(2), 69–75.
- Rahmawati, S., Roshayanti, F., Nugroho, A. S., & Hayat, M. S. (2021). Potensi implementasi Education for Sustainable Development (ESD) dalam pembelajaran IPA di MTs Nahdlatul Ulama Mranggen Kabupaten Demak. *Jurnal Kualita Pendidikan*, 2(1), 15–27.
- Rethlefsen, M. L., & Page, M. J. (2022). PRISMA 2020 and PRISMA-S: common questions

- on tracking records and the flow diagram. *Journal of the Medical Library Association: JMLA*, 110(2), 253.
- Rohmawati, Q., Siswanto, J., & Roshayanti, F. (2023). Kepraktisan dan Efektivitas Pembelajaran Konsep Dinamika Rotasi Berorientasi Education for Sustainable Development (ESD) Untuk Meningkatkan Keterampilan Berpikir Kreatif. *Jurnal Inovasi Pembelajaran Di Sekolah*, 4(1), 193–200.
- Sari, A. K., Hernani, H., & Supriatna, A. (2024). Pengembangan E-Modul Berbasis Education for Sustainable Development (ESD) pada Topik Bioplastik untuk Meningkatkan Literasi Sains Peserta Didik. *Jurnal Riset Dan Praktik Pendidikan Kimia*, 12(2), 137–146.
- UNESCO. (2017). Education for sustainable development goals: Learning objectives. Paris: UNESCO
- UNESCO. (2021). Berlin declaration on education for sustainable development. Paris: UNESCO.
- Vilmala, B. K., Kisworo, B., Rihan, H. G., & Syafriani, S. (2025). PjBL-ESD as an innovation in science learning: Cultivating local wisdom values and students' critical thinking skills. *Journal of Environment and Sustainability Education*, 3(1), 62–70.
- Viorezza, N., Hilyati, W., & Lasminingsih, M. (2023). Education for Sustainable Development: Bagaimana Urgensi dan Peluang Penerapannya pada Kurikulum Merdeka? *PUSAKA: Journal of Educational Review*, 1(1), 34–48.
- Zubaidah, S. (2016). Keterampilan abad ke-21: Keterampilan yang diajarkan melalui pembelajaran. *Seminar Nasional Pendidikan*, 2(2), 1–17.
- Zulfah, N. L. N., Purnamasari, S., & Abdurrahman, D. (2024). Implementasi problem based learning (PBL) terintegrasi education for sustainable development (ESD) terhadap literasi lingkungan siswa pada topik energi. *Jurnal Kajian Pendidikan IPA*, 4(1), 299–304.