Fostering a Generation of Sustainability Awareness: Strategies for Basic Education Based on a Systematic Literature Review

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Abstract. The increasing global environmental challenges highlight the urgent need to foster sustainability awareness from an early age. Elementary education serves as a critical phase for instilling values and attitudes that shape lifelong sustainable behaviors. This systematic literature review analyzes effective educational strategies for enhancing sustainability awareness among elementary school students. Guided by PRISMA 2020 protocols, a comprehensive search was conducted across Scopus, Dimensions, and Garuda databases, focusing on articles published between 2019 and 2024. Through a rigorous selection process, 25 studies were identified, offering insights into successful interventions. Findings categorize these strategies into three key approaches: experiential and project-based learning, curriculum integration, and digital interactive tools. Experiential learning engages students in hands-on activities, fostering emotional connections to environmental issues. Curriculum integration, particularly in science and social studies, enhances students' holistic understanding of sustainability. Meanwhile, digital tools such as educational games and simulations boost engagement and accessibility, though challenges related to technological infrastructure and teacher readiness remain. The review concludes that a multi-faceted approach combining experiential, curricular, and digital strategies offers the greatest potential for cultivating sustainability awareness. By implementing these integrated and context-specific strategies, educators and policymakers can design impactful and sustainable environmental education programs that prepare the next generation to address global environmental challenges..

Keywords: Sustainability awareness, elementary education, environmental education, literature review.

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INTRODUCTION

The world's growing environmental challenges underscore the urgent need to cultivate sustainability awareness from an early age. Elementary education represents a pivotal stage for embedding values and attitudes that foster responsible environmental behavior. Research suggests that awareness and attitudes developed during this phase significantly influence sustainable behaviors throughout life (Hnatyuk et al., 2024; Otto et al., 2019). Educational interventions, such as experiential learning and collaborative activities, have demonstrated positive outcomes in enhancing students' understanding of environmental issues (Shutaleva, 2023; van de Wetering et al., 2022). However, there remains a pressing need to explore effective, integrative approaches tailored to elementary schools to strengthen students' sustainability awareness.

The increasing research focus on environment-related education highlights the importance of this field in addressing global challenges. As shown in **Fig. 1**, the number of publications on "environmental" and "education" has grown significantly over the past decade, with 37,460 articles published between 2014 and 2024 and a peak in 2024 with 5,297 articles. This trend emphasizes the relevance of developing educational strategies to instill sustainability awareness.

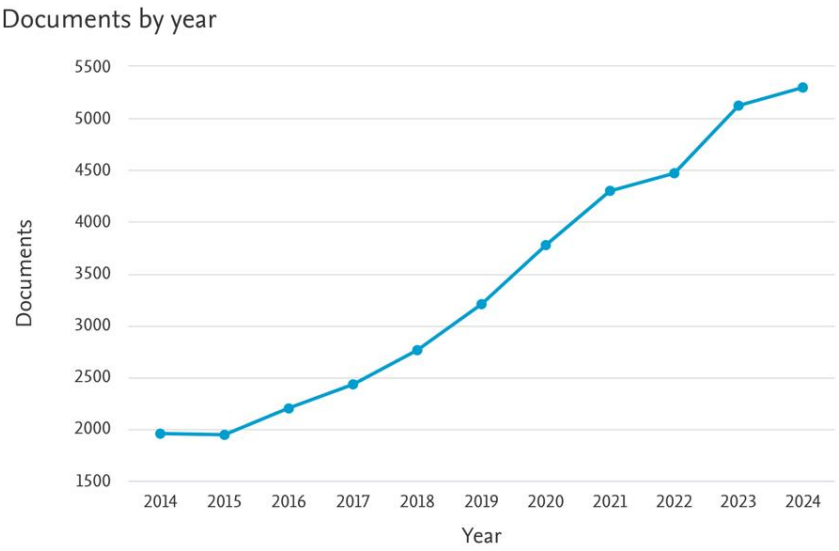

Figure 1. Research tend based on Scopus database using keywords "environmental" and "education" taken on 8 November 2024. Detailed information how to take bibliometric is shown elsewhere (Hidayat et al., 2024).

Several studies have examined different teaching methods to instill sustainability values in elementary students. For example, experiential learning approaches, such as outdoor activities and direct engagement with environmental projects, have been shown to foster emotional connections to nature, enhancing students' sense of environmental stewardship (Okur-Berberoglu, 2017). Similarly, project-based learning encourages students to collaborate on solving real-world environmental issues, promoting critical thinking and environmental responsibility (Bramwell-Lalor et al., 2020; Kricsfalusy et al., 2018). Digital tools, including educational games and virtual reality simulations, have also been effective in making sustainability topics more engaging and accessible for young learners (Klopfer & Squire, 2008; Klopfer & Yoon, 2005; Lu & Liu, 2015). These approaches underscore the need for sustainability education to be interactive, integrated, and developmentally appropriate for elementary students.

Despite these documented successes, existing research faces notable limitations. Most studies focus on short-term outcomes, such as increased awareness, without addressing the long-term sustainability of behavioral changes. Furthermore, standardized evaluation methods to measure the lasting impacts of sustainability education are still underdeveloped. This gap highlights the need for longitudinal studies to evaluate how sustainability awareness cultivated in elementary education influences behaviors in later stages of life.

To address these gaps, this systematic literature review aims to identify the most effective educational strategies for fostering sustainability awareness among elementary school students. By synthesizing findings across studies, this review also seeks to uncover critical

research gaps, providing actionable insights for educators and policymakers to design curricula that inspire a sustainability-conscious generation.

METHODOLOGY

A systematic literature review approach was employed to achieve the study's objectives and offer a thorough understanding of experimental opportunities within green chemistry education. In conducting the review, we adhered to the updated Preferred Reporting Items for Systematic Reviews (PRISMA) 2020 guidelines (Page et al., 2021), which emphasize transparency, replicability, and scientific rigor in systematic reviews. A protocol was thus developed to clarify the research questions and outline the selected information sources, search methodology, inclusion and exclusion criteria, data extraction, and analysis processes.

Sources of Information and Search Strategies

The systematic literature review conducted in this study involved a comprehensive search of articles published between 2019 and 2024 in three electronic databases: Scopus, Dimensions and Garuda. These databases were chosen for their globally and nationally recognized impact metrics, as well as for their extensive peer-reviewed scientific content spanning multiple fields and disciplines (Study, 2019; Susan Fingerman, 2006). The search strategy incorporated key concepts related to the research focus (e.g., sustainability awareness, primary school students, and learning) and research question, utilizing Boolean operators (AND, OR) with parentheses to effectively structure the search string (Kalogiannakis et al., 2021). After initial testing and adjustment to the syntax requirements of each database, the completed search strings were created (Table 1).

Table 1. Information source and search strategy.

Information Source	Search String and Parameters
Scopus (https://www.scopus.com/)	TITLE-ABS (sustainability AND awareness) AND TITLE (primary AND school) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (OA , "all"))
Dimensions (https://www.dimensions.ai/)	Keywords: "sustainability awareness" "primary school" Publication Year: 2024 OR 2023 OR 2022 OR 2021OR 2020 OR 2019 Publication Type: Article OR Proceeding Search by: Abstract
Garuda (https://garuda.kemdikbud.go.id/)	Keywords: "kesadaran berkelanjutan" "siswa sekolah dasar" Filter by year: form 2019 to 2024

This study included only research articles published in academic journals. During the search process, additional filters were applied (document type: article, proceedings; language: English and Indonesian) in each database according to the inclusion and exclusion criteria outlined in next section. To ensure a comprehensive overview, certain journals were intentionally excluded

during the search strategy phase (Vojíř & Rusek, 2019). The final search across all databases was completed on November 6, 2021.

Exclusion and Inclusion Criteria

To ensure the selection of only studies relevant to our research topic from the databases, specific inclusion and exclusion criteria were established.

1. Exclusion Criteria
ECr1: Book chapter, book, conference review, editorial, note, short survey, erratum, retracted, letter, report, and data paper.

ECr2: The study is not written in English or Indonesian.

ECr3: The study is listed in another database.

ECr4: The study was not conducted in a primary school education setting

ECr5: The study is not related to science subjects.

ECr6: he full text of the study is not available.

ECr7: This study does not address experimental work in an effort to raise awareness of the sustainable environment of elementary school students.

2. Inclusion Criteria
ICr1: Journal articles and proceedings of conferences.

ICr2: The study is written in English or Indonesian.

ICr3: The study is not listed in another database.

ICr4: This research was conducted in a primary education setting.

ICr5: The research is related to science learning.

ICr6: Full text of the study is available or open access.

ICr7: The study includes efforts to increase students' sustainability awareness.

Data Collection and Analysis

The systematic literature review was carried out in five stages, adhering to the PRISMA 2020 guidelines (Page et al., 2021). In the first stage, an initial literature search was performed across the electronic databases Scopus (n = 16), Dimensions (n = 142), and Garuda (n = 46). Applying inclusion (**ICr1**, **ICr2**) and exclusion (**ECr1**, **ECr2**) criteria, 58 papers were removed—filtered by both the database automation tool and manual review—because they did not meet the requirements for paper type or language. Additionally, based on further inclusion and

exclusion criteria (**ICr3**, **ECr3**), 11 duplicate papers were identified and excluded using Microsoft Excel.

In the second stage, inclusion (**ICr4**, **ICr5**) and exclusion (**ECr4**, **ECr5**) criteria were applied by examining the titles and abstracts of 135 papers. When abstracts were insufficient or unclear, the entire paper was consulted. A total of 92 articles were deemed ineligible as they were outside the context of primary school learning or unrelated to the field of science. Additionally, three papers without full-text access were excluded from further analysis (**ICr6**, **ECr6**). In the fourth stage, 40 papers were carefully evaluated for eligibility based on inclusion (**ICr7**) and exclusion (**ECr7**) criteria. Finally, in the fifth stage, the full texts of the remaining 25 papers were thoroughly assessed for relevance to our criteria and research questions. This process is summarized in the PRISMA flowchart (Fig. 2).

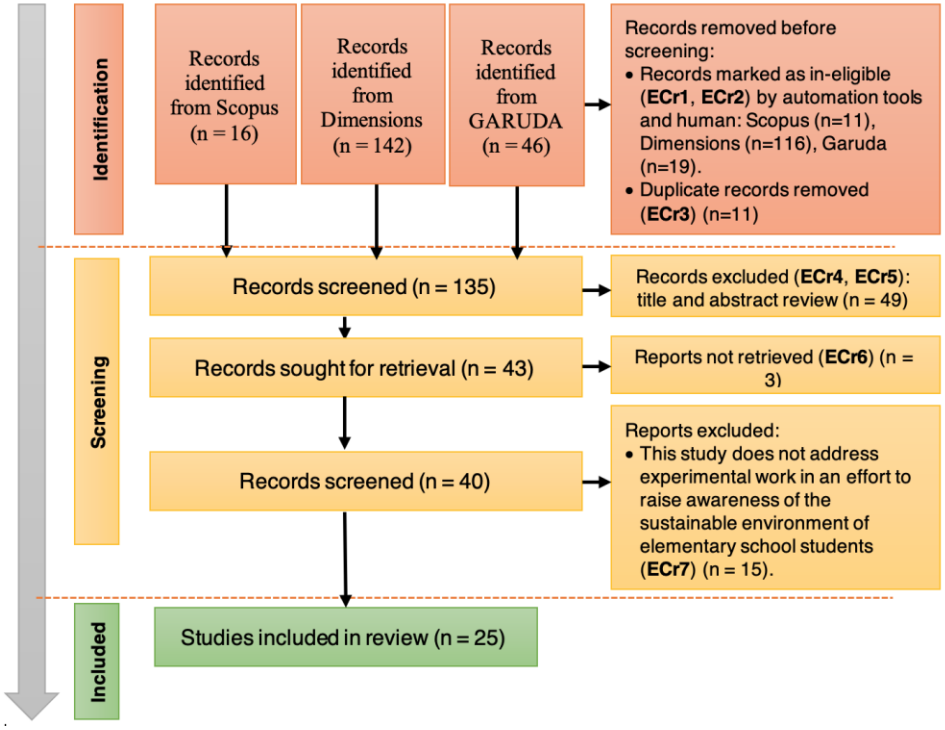

Figure 2. PRISMA 2020 flow diagram.

Data analysis in this research uses thematic analysis. Thematic analysis is a method for identifying, analyzing, and reporting themes or patterns in data. Essential parts of each theme are extracted. (Braun & Clarke, 2006) explains that there are six steps in thematic analysis. The first step is data identification, the second step is data coding, the third step is looking for themes and compiling the codes, the fourth step is applying codes to the data, the fifth step is determining themes, and the sixth step is making a report on themes and linking them back to the research questions.

RESULTS AND DISCUSSION

This research is a systematic literature review by analyzing 25 articles on efforts to increase elementary school students' sustainability awareness in science learning. Based on the research methodology, 7 articles used quantitative methods, 9 article used qualitative methods, 4 articles used mixed methods, 2 articles were development research, 1 Clasroom Action Research, 1 Quasi Experiment, and 1 *Design Science Research* (DSR) The findings also highlighted various efforts that have been made as an illustration to replicate or modify for future research and steps. A summary of the systematic literature review is presented in Table 2.

Table 2. A summary of the systematic literature review on efforts to raise awareness of the sustainable environment of primary school students over the past five years (2019-2024).

Author	Method	Findings
(Kluczkovski et al., 2024)	Mixed Methods	The program increased students' understanding of sustainability, climate change and healthy food production. Student engagement was high in the practical activities, but logistical challenges such as aquapod maintenance, fish availability, and time constraints in school schedules were encountered.
(Alzuhair et al., 2024)	Descriptive qualitative research	Science books showed the highest integration of green consumption values, followed by math and English. Values such as environmental awareness and environmental sustainability were most prevalent in science books, but some values, such as the use of environmentally friendly products, were less prevalent. Shortcomings were also found in math and English books in covering these values.
(Shih, 2024)	Qualitative research	The social curriculum implemented is based on the local environment and designed to enhance students' sustainability competencies, such as system thinking, collaboration, and action skills. Students are actively involved in observing and studying the local environment to increase their awareness of sustainability.
(Da Silva et al., 2024)	Qualitative research	Environmental education through toy-making activities from recycled materials increases students' awareness of environmental conservation. The use of toys and games improves students' cognitive and social skills, supporting inclusive and participatory learning.
(Setyaningsih et al., 2024)	Descriptive qualitative research	Environment-based education is proven to improve children's ecological literacy and naturalistic intelligence, especially in the aspects of knowledge, practical skills and positive attitudes towards preserving the coastal environment. Children showed an increased understanding of coastal ecosystems and the importance of protecting the environment.
(Muela-Bermejo & Pérez-Martínez, 2024)	Qualitative research	Critical reading learning can improve students' understanding of environmental issues and support sustainability attitudes. Two main categories of findings: ecocritical awareness development and sustainability content learning.

Author	Method	Findings
(Rifa'i et al., 2024)	Research and Development (R&D)	The motion graphic educational video was effective in increasing students' understanding and engagement with waste management, with student satisfaction in the good category. Students are more interested and understand the material through this visual approach.
(Djanegara et al., 2024)	Classroom Action Research	Significant improvement in students' environmental awareness and pro-environmental behavior after using coding in solving clean energy related problems. Students also showed positive perceptions of coding.
(Sutinah et al., 2023)	Descriptive quantitative	Students have high sustainability awareness, especially in the knowledge aspect and environmental dimension. The behavioral aspect has a lower score, indicating that understanding does not always drive action.
(Khoirun Nisa et al., 2023)	Mixed Methods	90% of students understand the importance of plants for environmental sustainability and show positive actions in caring for plants. The game is effective as an engaging sustainability learning medium.
(Menkhoff & Gan, 2023)	Mixed Methods	*Climate Bot 1.0* increases student awareness of climate change and adaptation through interactive digital content. Students showed higher engagement in sustainability and climate action awareness after using the chatbot. The chatbot is effective in supporting sustainability-related learning objectives.
(Senior et al., 2023)	*Design Science Research* (DSR)	Environmental education through toy-making activities from recycled materials increases students' awareness of environmental conservation. The use of toys and games improves students' cognitive and social skills, supporting inclusive and participatory learning.
(Goel et al., 2023)	Descriptive Quantitative	The majority of students demonstrated awareness of climate change and its impacts, but there were gaps in their in-depth understanding of concepts such as carbon footprint. Social media was identified as a key tool for information dissemination, and most students supported the addition of environment-related activities in schools.
(Adawiah & Anggraini, 2023)	Quantitative research	The Adiwiyata program has a significant influence on students' environmental awareness. Students showed better attitudes in terms of maintaining cleanliness and participating in environmental activities such as waste banks and eco-bricks. Environmental knowledge and direct involvement increased student concern.
(JIMOLA & OMODUN, 2023)	Descriptive Qualitative Research	Teachers showed positive perceptions of picture books and animated cartoons for environmental literacy learning, with benefits in improving students' memory and understanding. However, various barriers were encountered, including a lack of technical facilities and infrastructure, limited funding, unstable internet connections and time constraints.
(Feio et al., 2022)	Quantitative research	After one year, the children's knowledge of the river ecosystem and biodiversity increased and their fear of nature decreased. The children better understood the importance of the river ecosystem, identified specific animals and plants, and realized negative human impacts such as litter and changes in riparian vegetation.

Author	Method	Findings
(Sarbaini et al., 2022)	Descriptive Quantitative research	Environmental education that focuses on local values is proven to improve students' understanding of environmental issues. Topics such as urban land use, wise water use and domestic waste management were proposed as part of the curriculum. Teachers and students showed positive responses to locally-based environmental themes.
(Syofyan et al., 2020)	Research and development	The environmental literacy-based module with a scientific approach effectively improved learning outcomes with an average increase of 28%. Students responded positively, showing better understanding in science concepts and increased environmental awareness. Scientific-based learning motivates students' active involvement in the exploration of environmental materials.
(Berze et al., 2022)	Quantitative research	The findings showed three valid factors on the NEP scale for children: Questioning of Human Intervention, Rights of Nature, and Eco-Crisis, which were significantly related to demographic factors and pro-environmental behaviors. This study highlights the complexity in the structure of environmental attitudes in children and the importance of cultural understanding.
(Botella et al., 2022)	Quasi Experiment	Although there were improvements in some aspects of ecological awareness such as reuse and recycling, no significant differences were found between the experimental and control groups. Student engagement increased, however, the duration of the intervention may have been too short to produce significant changes in attitudes.
(Aledamat et al., 2021)	Mixed Methods	The program was effective in improving students' problem-solving skills. The pre-test and post-test results showed significant improvements in students' understanding and attitudes towards environmental issues. In addition, the collaborative approach strengthened students' experimental skills and self-efficacy. The program faced challenges such as limited laboratory experiments and the need for daily feedback.
(Sharma & Rani, 2020)	Descriptive Quantitative research	Students' awareness of environmentally sustainable consumption is at a moderate level. There were significant differences in awareness levels based on gender, school type and grade. Students in government schools showed higher environmental awareness than private schools, despite limitations in infrastructure in government schools. In addition, female students showed slightly higher levels of environmental awareness than males.
(Saba Tariq et al., 2020)	Qualitative Content Analysis	The Canadian and Turkish curricula are more comprehensive in their integration of environmental concepts than Pakistan. Canada focuses more on waste management and field practices, while Turkey includes biodiversity conservation concepts. In Pakistan, environmental practices are still at an early stage with limited resources and teacher training.
(D'Addezio, 2020)	Descriptive Qualitative research	Children demonstrate a deep understanding and sensitivity to geoscientific phenomena and environmental issues. Images reflect a positive perspective towards science, environmental awareness and confidence in the ability of science to solve global problems.

Author	Method	Findings
(Apriana & Bahri, 2020)	Descpriptive Qualitative research	Students' inquiry activities were low (29%) while scientific attitudes were moderate (61%), indicating the need for improvement through inquiry-based learning models and scientific attitudes.

A review of 25 studies related to raising the sustainability awareness of primary school students in table 1 shows a variety of strategies that integrate hands-on learning, environmental literacy, and the use of digital and interactive tools. These approaches provide important insights for raising environmental awareness among young learners, in line with the aim of this study, which is to identify the best methods for fostering sustainable behavior through learning activities. The analysis highlights three main categories in pedagogy: experiential learning, curriculum integration and digital engagement, each of which has strengths and areas for improvement. A collection of articles addressing these three categories can be seen in Table 3.

Table 3. Categorization of studies highlighting three main categories in pedagogy.

The main categories in pedagogy	Authors
Experiential and Project-Based **Learning** Approaches	(Kluczkovski et al., 2024), (Da Silva et al., 2024), (Setyaningsih et al., 2024), (Adawiah & Anggraini, 2023), (Feio et al., 2022), (Sarbaini et al., 2022), (Saba Tariq et al., 2020)
Curriculum integration and **environmental literacy**	(Alzuhair et al., 2024), (Da Silva et al., 2024), (Setyaningsih et al., 2024), (Sarbaini et al., 2022), (Syofyan et al., 2020), (D'Addezio, 2020)
D**igital and interactive learning tools**	(Rifa'i et al., 2024), (Djanegara et al., 2024), (Menkhoff & Gan, 2023), (Senior et al., 2023), (Goel et al., 2023), (JIMOLA & OMODUN, 2023)

Experiential and Project-Based Learning Approaches

Studies consistently show that experiential learning has a significant impact on elementary school students' understanding of and commitment to sustainability. Projects that involve direct interaction with the environment, such as outdoor activities and waste management practices can build an emotional connection to sustainability efforts (Kluczkovski et al., 2024; Okur, 2017). This emotional engagement is important to encourage environmentally friendly behavior. In addition, (Feio et al., 2022) found that continuous interaction with ecosystems, such as biodiversity education, not only increases students' ecological knowledge but also reduces fear of nature, thus fostering a deep love for the environment. This result is supported by (Setyaningsih et al., 2024) which shows that environment-based education in coastal areas improves children's ecological literacy and naturalistic intelligence.

Project-based learning (PBL) also plays an important role by allowing students to collaborate in solving real-world problems. For example, Saba Tariq et al., (2020), highlighted the effectiveness of collaborative projects in waste management to shape environmental responsibility. In contrast to previous studies that focused on a single activity, this review emphasizes the importance of combining PBL with local community engagement in order for sustainable behaviors to be formed consistently and sustainably. The findings emphasize the need to design activities that are not only engaging but also sustainable and relevant to the local context. Approaches such as school greening projects that involve parents and communities can strengthen the impact of sustainability education at the primary school level.

Curriculum Integration and Environmental Literacy

Integrating sustainability themes into various subjects emerged as a strong theme in this study. Integrative approaches, especially in subjects such as science, social studies and mathematics, have been shown to improve students' understanding of sustainability concepts. For example, Alzuhair et al., (2024) found that science textbooks containing environmentally friendly values were more effective in conveying sustainability concepts. Furthermore, Sarbaini et al., (2022) emphasized the importance of aligning local issues, such as land use and water conservation, with curriculum content. This allows students to better understand environmental issues in their own communities. In addition, Shih, (2024) points out that an environment-based curriculum helps students develop systematic thinking competencies and sustainability action skills.

Although this approach has many advantages, challenges remain, especially in ensuring uniform implementation across different educational settings. Many schools in rural or less developed areas do not yet have access to adequate teaching materials or teacher training that supports sustainability integration. Therefore, this review recommends the development of flexible curriculum guidelines that can be adapted to local contexts without compromising national education standards.

Digital and Interactive Learning Tools

The integration of digital tools such as educational games, virtual reality and interactive media has shown positive results in increasing student engagement with sustainability issues. (Senior et al., 2023) reported positive results from the use of Game ByMaker simulations in teaching sustainable urban planning, which improved student understanding and engagement. Meanwhile, Menkhoff & Gan, (2023) found that the Climate Bot 1.0 chatbot was effective in increasing students' awareness of climate change actions. Digital tools not only make learning more accessible, but also provide an engaging interactive experience for students. Rifa'i et al.,

(2024) showed that motion graphic videos were effective in conveying waste management concepts to students, which increased their understanding and interest in sustainability topics.

However, significant challenges in implementing digital tools include limited technological infrastructure and lack of teacher training in many schools, especially in remote or less developed areas (JIMOLA & OMODUN, 2023). Overcoming these barriers requires the support of the government and relevant parties to ensure equitable access to educational technology and provide regular training for teachers in the use of digital tools.

CONCLUSION

This systematic literature review identified three main effective approaches to raising sustainability awareness in primary school students: experiential and project-based learning, curriculum integration, and the use of digital and interactive tools. The combination of these three approaches proved to be more comprehensive and sustainable than applying the methods separately. Experiential learning helps students build an emotional connection to the environment, curriculum integration expands cross-disciplinary understanding by linking sustainability concepts to local issues, and digital tools increase student engagement through interactive and accessible learning. However, challenges such as limited resources, lack of teacher training, and logistical barriers to implementation still need to be overcome. Therefore, an integrated and sustainable education strategy is needed, supported by quality teacher training, equitable technology infrastructure and long-term evaluation. By applying this approach, sustainability education programs can significantly shape the eco-friendly behavior of the younger generation and have a positive impact in the long run.

Recommendations

Findings from this study suggest that a multi-faceted approach combining experiential learning, curriculum integration, and the use of digital tools is the most effective way to increase the sustainability awareness of elementary school students. Below are specific recommendations for the implementation of sustainability education programs:

1. Develop a Contextualized Program.
   Design programs that integrate experiential projects with digital technologies according to local environmental challenges (Sarbaini et al., 2022). For example, marine conservation projects in coastal areas supported by digital simulations of marine ecosystems.

2. Teacher training and support.
   Provide regular training to teachers to integrate sustainability and technology in daily learning processes (Sharma et al., 2020).

3. Resource Provision.
   Ensure adequate resource allocation and infrastructure to support the use of digital tools and implementation of environmental projects (Goel et al., 2023).

4. Longitudinal Research.
   Conduct long-term research to measure the effectiveness of the integrated approach in shaping students' sustainability behavior consistently (Sutinah et al., 2023).

By considering logistical support, teacher training, and consistent evaluation, this program can overcome barriers such as limited resources and technology infrastructure that vary from school to school.

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