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Review Paper

Cultivating Green Minds: A Systematic Review of Teaching Strategies, Outcome and Challenges in Education for Sustainable Development (ESD) for Secondary Schools

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Abstract: This study conducts a systematic literature review to provide a comprehensive analysis of teaching strategies implemented in secondary schools for the integration of Education for Sustainable Development (ESD). Despite the global emphasis on ESD, a systematic comparison of teaching strategies' efficacy in secondary schools remains underexplored, particularly in diverse cultural contexts. The research explores prevalent teaching approaches, evaluates their outcomes, and identifies barriers and challenges encountered during implementation. To address this gap, the study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A meticulous analysis of 23 studies (2019–2024) from Scopus, Web of Science, and ERIC reveals that Project-based Learning (PjBL) dominates (48% of studies), significantly enhancing systems thinking and collaborative skills while Digital-based Learning (DBL) (30% of studies) proves most effective in technology-rich environments. Four key implementation challenges emerge, including the insufficient training of teachers, the lack of teaching materials, insufficient understanding of how to implement ESD and teachers' preference for subject-specific over cross-disciplinary approaches. These findings offer a research-backed foundation for selecting effective strategies, calling on policymakers to adopt flexible ESD frameworks tailored to local contexts while advancing SDG 4.7 objectives. Such efforts can narrow the longstanding divide between ESD principles and classroom implementation, enabling secondary schools globally to foster environmentally and socially conscious learners prepared for complex future demands.

Keywords: Education for Sustainable Development; ESD; systematic literature review; secondary school; sustainability;teaching approaches

Introduction

Education for Sustainable Development (ESD) has emerged as a vital response to global challenges, addressing issues of environmental degradation, social inequality, and economic instability (Norden & Avery, 2021). Yuan et al. (2022) underscore its pivotal role in tackling global development challenges, aligning with Sustainable Development Goal 4 (SDG 4). UNESCO (2015) emphasizes the importance of education in sustainable development, particularly through target 4.7, promoting ESD and a student-centered curriculum. Furthermore, UNESCO (2020) state the definition of ESD as an initiative to provide students with knowledge, skills, and values for addressing current global challenges related to issues of climate change and unsustainable resource use, empowering them to make decisions and take collective action. Educational institutions can transform their curricula to center sustainability through active learning pedagogies, which cultivate critical thinking skills and global citizenship competencies while empowering students to engage meaningfully with sustainable practices (Wan Nor Azmi et al., 2024). Recent research highlights the integration of sustainability

principles into secondary education, shaping environmentally conscious and socially responsible youth (Kwee et al., 2023; Janhonen et al., 2023). The global call for sustainable development necessitates exploring how ESD is integrated into secondary education, contributing to a more environmentally conscious and socially responsible youth (Lochner et al., 2021; Vare 2021; Yuan 2022). Beyond knowledge acquisition, secondary education plays a crucial role in cultivating attitudes and skills essential to students' roles as responsible global citizens (Chiba et al., 2021; Georgiou et al., 2023).

The urgency of the sustainability agenda is underscored by interconnected challenges such as climate change, environmental degradation and social inequities (Kleespies & Dierkes, 2020; Shivanna 2022; Suraci et al. 2023). Recognizing education's pivotal role, UNESCO (2017) advocates transformative changes to ensure quality education for all. Schools are vital hubs that prepare students to drive sustainability efforts, fostering greater awareness and action for a sustainable future (Mahat & Idrus, 2016). In recent years, research and practice surrounding ESD in secondary schools have gained momentum (Fiel'ardh et al., 2023; Raman et al.,2023). Various pedagogical approaches, curriculum designs, and extracurricular activities have been explored to embed sustainability principles into the educational experience (Said et al.,2021; Linkwitz, 2022; Nguyen, 2023). Despite increasing awareness of sustainability issues, three critical research gaps remain in secondary school ESD implementation: (1) effective interdisciplinary integration beyond single subjects, (2) development of age-appropriate pedagogical approaches, and (3) systemic barriers to institutional adoption (Karim et al., 2022; Gericke et al., 2022; Olsson et al., 2022). This focus on secondary education is particularly crucial because adolescents are at a developmental stage where they begin to connect abstract sustainability concepts with real-world actions (Yuan et al., 2022), yet current approaches rarely use to leverage this potential. The integration challenge has two key aspects: First, sustainability principles must transcend traditional subject boundaries to become a cross-curricular priority (Hamwy et al., 2023). Second, secondary schools require specialized strategies that address both the cognitive abilities of adolescent learners and the institutional constraints of formal education systems (Kefalaki, 2023).

The overarching objective of this study is to comprehensively investigate the integration of Education for Sustainable Development (ESD) in secondary schools, identifying teaching strategies and its outcome, understanding barriers, and contributing to the academic discourse on ESD integration at the secondary level. This comprehensive strategy is specifically designed to offer valuable perspectives that can influence policy decisions, assist educators, and contribute to the ongoing conversation about the optimal integration of Education for Sustainable Development (ESD) into secondary school curricula. While crafting research questions for this systematic literature review, we followed the PICO model to structure and direct our efforts toward accomplishing the research goal. Eriksen and Frandsen (2018) state that the PICO model is commonly utilized as a tool to organize research questions in relation to evidence syntheses. Within this model, P represents Population, focusing primarily on secondary school students. I denotes Intervention, specifically emphasizing the integration of Education for Sustainable Development (ESD). C signifies Comparison, involving alternative instructional strategies. Finally, O stands for Outcome, encompassing the effectiveness of ESD programs in secondary schools. Consequently, three research questions have emerged;

i. What is the teaching strategies that commonly used to integrate ESD in secondary schools?
ii. What are the outcomes of different teaching strategies in integrating ESD in secondary schools?
iii. What barriers and challenges during teaching in integrating ESD in the secondary schools?

Methodology

1. Research Design

This study employed the PRISMA guidelines for the execution of a systematic literature review, as illustrated in Figure 1. According to Sofwan et al. (2024) PRISMA offers three notable benefits. Firstly, it facilitates the exploration of specific research topics, enhancing the systematic nature of the research. Secondly, it establishes clear exclusion and inclusion criteria. Thirdly, PRISMA aims to analyze a substantial volume of

scientific publications within a defined timeframe. The review process comprised four distinct stages: identification, screening, eligibility, and quality appraisal (Page et al.2020).

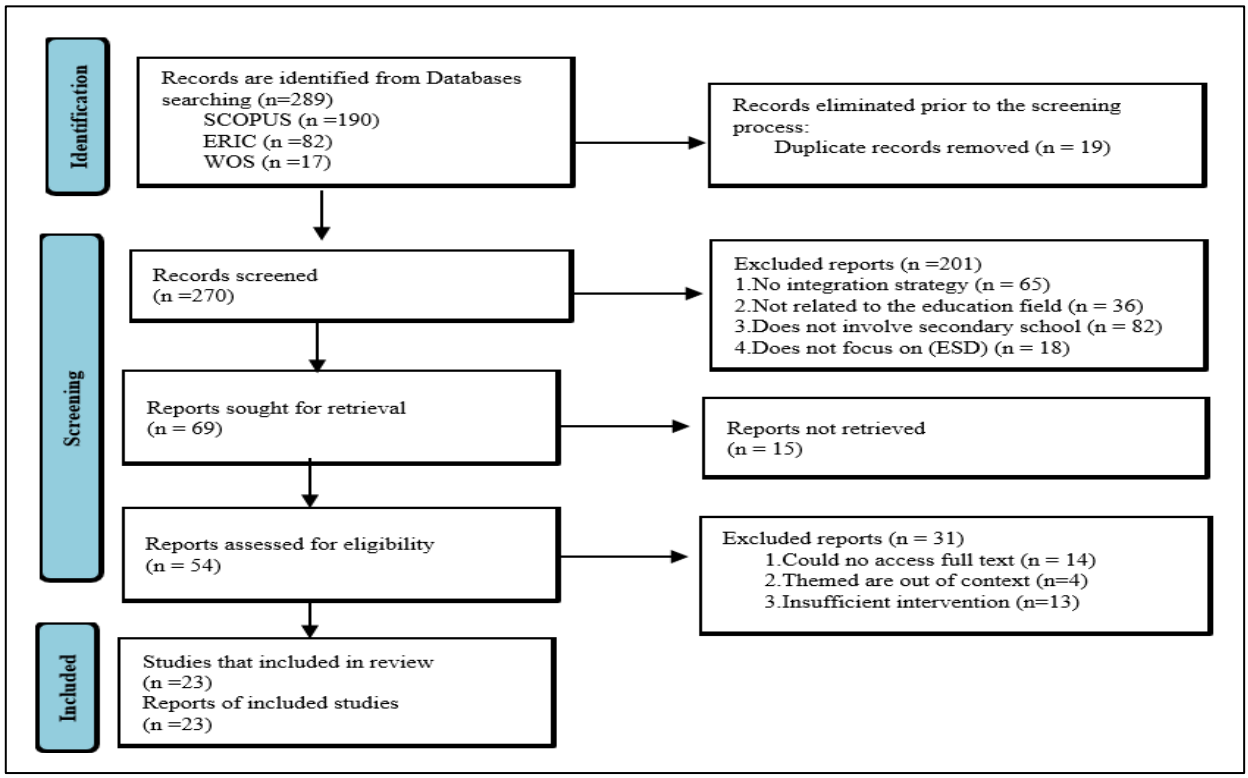

Figure 1. A flow diagram illustrating the study selection process adapted from the PRISMA diagram
Source: (Page et al.2020)

2. Searching Procedure

This study employed an advanced search method across three primary databases: SCOPUS, Web of Science (WOS), and Education Resources Information Center (ERIC). The strategic selection of Scopus, Web of Science, and ERIC ensures comprehensive coverage through three complementary strengths: Web of Science and Scopus contribute methodological rigor via their selective indexing of high-impact journals, while ERIC provides essential contextual relevance through its practitioner focused resources. This combination deliberately excludes databases that either lack disciplinary applicability to education research or offer insufficient coverage of sustainable development topics. To refine the precision of advanced queries, the researcher utilized the phrase searching feature and integrated Boolean operators such as OR and AND as shown in Table 1. The review process unfolded through four consecutive steps, outlined in the following subsections.

Table 1. Search string on three database

Database	Search string
SCOPUS	title-abs-key= (("Integrat*" OR "implemen*") AND ("Sustainability Education" OR "ESD" OR "education for sustainable development" OR "environment education") AND ("in") AND ("Secondary Schools" OR "high school" OR "secondary education"))
ERIC	(("Integrating*" OR "implementing*") AND ("Sustainability Education" OR "ESD" OR "education for sustainable development" OR "environment education") AND ("in") AND ("Secondary Schools" OR "high school" OR "secondary education"))
Web Of Science	TS= (("Integra*" OR "implemen*") AND ("Sustainability Education" OR "ESD" OR "education for sustainable development" OR "environment education") AND ("in") AND ("Secondary Schools" OR "high school" OR "secondary education"))

First step: Identification

During the initial phase, known as the identification stage, we employed an expanded set of keywords to refine the selection and broaden the pool of potential articles. The aim was to increase the likelihood of retrieving more relevant articles. The primary keywords were derived from the research question, and following the guidance of Kitchenham and Charters (2007), the researcher categorized the research question into three distinct domains: Integrating, Education for Sustainable Development (ESD), and secondary school. These selected keywords played a crucial role in ensuring thoroughness during the identification phase, facilitating the identification of synonyms, related terms, and variations. Throughout this stage, the search covered all databases, utilizing the identified terms within the title, abstract, or keywords. The search outcomes were subsequently assessed based on the inclusion and exclusion criteria specified in Table 2.

Table 2. The icnlusion and exclusion of criteria

Criterion types	Inclusion	Exclusion
Language	In English	Non-English
Document types	Journal articles	Conference proceeding or book or dissertation or theses
Topic	In the title, abstract, or keywords, the words “integrating", “ESD" and "Secondary school or High School” appear.	Other words or terms stated
Recency	Published between 2019 and 2024	Before 2019
Findings	They present their findings regarding the integrating of ESD in secondary schools	No impact reported on their findings

Second step: Screening

The screening procedure rigorously applied the inclusion criteria outlined in Table 1 to ensure methodological consistency and relevance. As emphasized by the reviewers, particular attention was given to: (1) peer-reviewed journal articles in English to maintain academic rigor and consistency in analysis; (2) explicit topical focus requiring the terms "integrating," "ESD," and either "Secondary school" or "High School" to appear in titles, abstracts, or keywords; and (3) contemporary publications (2019-2024) to capture current pedagogical approaches. To address concerns about methodological transparency, we documented that 201 of 270 initially identified articles were excluded during preliminary screening primarily for: (a) non-journal publication types (e.g., dissertations, conference proceedings), (b) irrelevant educational levels (e.g., primary or tertiary focus), or (c) insufficient empirical findings about ESD integration. This stringent process aligns with PRISMA standards for systematic reviews and ensures the selected studies directly address our research objectives.

Third step: Eligibility

In the third step, the eligibility stage entailed a comprehensive examination of the entire article texts. This involved reviewing the title and abstract, emphasizing four specific inclusion criteria.: 1) The articles must explicitly discuss teaching strategies as an intervention for the integration of Education for Sustainable Development (ESD), 2) the teaching strategy should primarily target secondary schools curriculum, and 3) the article should shown the strategy of implimenting ESD to evaluate the outcome of teaching strategies. Consequently, only articles targeting secondary school students were chosen in this study. This ultimate eligibility phase has reduced the study to a selection of 23 articles for further examination.

Four step: Quality Appraisal

During the fourth step, which encompasses quality appraisal, two reviewers were individually assessed each of the remaining articles, placing particular emphasis on the abstract, methodology, and main findings. In accordance with the guidelines suggested by Petticrew and Roberts (2008), the reviewers assigned a quality rating to each article, classifying them as low, moderate, or high. Only articles determined to be of moderate or high quality were included for consideration. The reviewers systematically assessed the quality of articles regarding theme of Education for Sustainable Development (ESD) using a set of five criteria, adapted from Hong et al. (2018) guidelines. These criteria included: 1) prioritization of integrating teaching strategies for

enhancing ESD, 2) inclusion of methodologies to identify indicators for the outcome of ESD teaching strategies, 3) explicit articulation of the approach to integrating ESD in the articles, 4) adequacy of justifications for ESD integration recommendations, and 5) provision of recommendations or guidance on activities promoting ESD teaching strategies. Each criterion had three response options: yes, no, or cannot tell. Through unanimous consensus among reviewers, 23 articles meeting the specified high or moderate quality criteria were included in this study.

The Findings

In this section, we present the outcomes of our systematic literature review, aligning with the overarching objectives set forth in the study. The primary aim of our investigation was to identify and analyze teaching strategies for the integration of Education for Sustainable Development (ESD) in secondary school curricula. Through a thorough review process, we evaluated the outcome of current teaching strategies and initiatives related to Education for Sustainable Development (ESD) and identified barriers and challenges in their implementation.

Additionally, we sought to identify gaps in the current literature on integrating ESD in secondary schools and proposed potential areas for future research. The results presented herein encapsulate a comprehensive synthesis of the literature, shedding light on the current state of ESD integration in secondary education. The article examined 23 studies that assessed the outcome of teaching strategies in implementing Education for Sustainable Development (ESD) among secondary school students. The table 3 presented below provides a summary of teaching strategies categorized into four main strategies: Project-based Learning (PjBl), Problem-based Learning (PBL), Inquiry-based Learning (IBL) and Digital-based Learning (DBL).

Table 3. The finding of commonly used teaching strategies

No	Study	Country	Teaching strategies				Subject
			PjBL	PBL	IBL	DBL	
1	Gutierrez et al. (2024)	Spain			√		Multidicipline
2	Syskowski et al. (2024)	Germany				√	Chemistry
3	Janhonen et al. (2023)	Finland	√				Home Economics
4	Bettencourt et al. (2023).	Portugal	√				Multidicipline
5	Abdurrahman et al. (2023)	Indonesia	√				STEM
6	Linkwitz & Eilks (2022)	Germany	√				Chemistry
7	Rahmawati et al. (2022)	Indonesia	√				Chemistry
8	Li et al. (2022)	China				√	Geography
9	Eugenio-Gozalbo et al. (2022)	Spain		√			Multidicipline
10	Lochner et al. (2021)	Germany				√	Multidicipline
11	Istiana et al. (2021)	Indonesia		√			Science
12	Saragih et al. (2021)	Indonesia		√			Biology
13	Georgousis et al. (2021)	Grece				√	Multidicipline
14	Berman (2021)	Africa	√				Multidicipline
15	Paaske et al. (2021)	Denmark	√				Multidicipline
16	Vare (2021)	Europe	√				Multidicipline
17	Zidny et al. (2021)	Indonesia			√		Chemistry
18	Janakiraman et al. (2021)	India				√	Multidicipline
19	Derler et al. (2020)	Austria	√				Multidicipline
20	Bentz, J. (2020)	Portugal	√				Arts
21	Koenigstein et al. (2020)	Germany				√	Multidicipline
22	Neset et al. (2020)	Sweeden				√	Multidicipline
23	Ian et al. (2019)	Australia & Mauritius	√				STEM

Notes:PjBL= Project-based Learning; PBL= Problem-based Learning; IBL=Inquiry-based Learning; DBL= Digital-based Learning

1. Commonly Used Teaching Strategies for Integrating ESD in Secondary Schools

In the analysis presented in Table 3, the most common teaching strategy chosen for integrating Education for Sustainable Development (ESD) was identified as Project-based Learning, used in 11 out of 23 studies (48.0 %). Additionally, other frequently used teaching methods included Digital-based Learning (7; 30.0 %),

Problem-based Learning (3; 13.0 %), and Inquiry-based Learning (2; 9.0 %). A brief summary of these teaching strategies is provided in Figure 2.

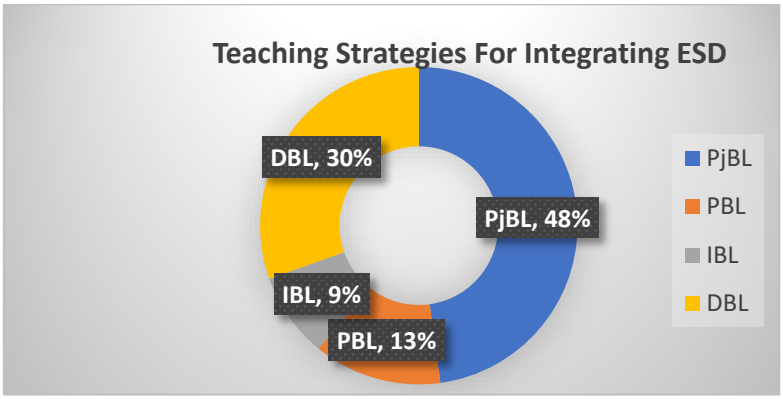

Figure 2. The common Teaching Strategies for Integrating ESD

Project-based learning (PjBL) is an instructional approach that prioritizes student-driven, experiential learning through projects (Rosli et al., 2024). This approach helps students build critical thinking, problem-solving, and teamwork skills while gaining a deeper understanding of the subject (Mutanga, 2024; Rupavijetra, 2022). Unlike traditional teaching, which often involves lectures with limited interaction, PjBL encourages students to explore, work together, and come up with creative solutions (Muzana, 2021). The hands-on nature of PjBL requires students to actively participate and collaborate, making it an effective way to improve learning outcomes and develop important skills (Isa, 2020; Almulla, 2020).

2. Outcome of Teaching Strategies for Integrating ESD in Secondary Schools

In exploring the outcomes of different teaching strategies for integrating ESD in secondary schools, a comprehensive examination of relevant studies has been conducted. This analysis aims to discern the results and impact of distinct teaching approaches. Table 4 encapsulates pivotal findings from the selected studies, highlighting the outcomes of these strategies. The findings provide valuable insights into how these strategies align with the intended objectives and their outcome in promoting ESD.

Table 4. The Outcome of Teaching Strategies

No	Study	Teaching Strategies	Activities	Outcome of Learning
1	Gutierrez et al. (2024)	IBL	Workshop with hands on activities	Increasing interest in learning and conservation of natural resources.
2	Syskowski et al. (2024)	DBL	Augmented Reality using tablet	Positive effects on interest in using tablets for education.
3	Janhonen et al. (2023).	PjBL	Collaborative participation	Influence on students' opinions of school meals
4	Bettencourt et al. (2023).	PjBL	Beach clean-up	Changes in students' knowledge, perceptions, behavioral intentions
5	Abdurrahman et al. (2023)	PjBL	STEM-EDP	Improved students' system thinking skills significantly
6	Linkwitz & Eilks (2022)	PjBL	Concept of green Chemistry	Comprehensive ESD integration based on green chemistry concept
7	Rahmawati et al. (2022)	PjBL	Specially written ethical dilemma stories	Deep chemistry learning and environmental awareness
8	Li et al. (2022)	DBL	Applying Web GIS	Educational benefits in natural disaster education
9	Eugenio-Gozalbo et al. (2022)	PBL	Organic learning garden	Educational improvements, environmental awareness

10	Lochner et al (2021)	DBL	Virtual School Garden Exchanges (VSGEs) via digital media	Impact on learners' perceptions, stereotypes, and norms
11	Istiana et al. (2021)	PBL	Mobile learning	Improve understanding of marine environmental education
12	Saragih et al (2021)	PBL	Systemic thinking and problem-solving.	Enhancing students' cognitive processes and problem-solving abilities.
13	Georgousis et al. (2021)	DBL	Synchronous online educational approach	Empowered students in geoheritage values.
14	Berman (2021)	PjBL	Tourism through an integrated approach	Understanding of global warming and climate change
15	Paaske et al. (2021)	PjBL	Action-oriented learning approach	Practical suggestions for redesigning traditional education
16	Vare (2021)	PjBL	Student-led, community-based actions	Benefits to students, potential societal impact
17	Zidny et al. (2021)	IBL	Sustainability-related socio-scientific issues (SSIs)	Improved argumentation skills
18	Janakiraman et al. (2021)	DBL	Using digital games	Improved environmental attitudes
19	Derler et al. (2020)	PjBL	Integrating real-world settings	Collaborative development of sustainable food products
20	Bentz (2020)	PjBL	Art-based practice	Transformative learning potential
21	Koenigstein et al. (2020)	DBL	Game Based Education Approach	Real-world problem-solving, collective learning
22	Neset et al. (2020)	DBL	Serious gaming	Engagement, reflection on challenges
23	Ian et al. (2019)	PjBL	Challenge-Based and Action Learning	Awareness, engagement, motivation, and action orientation towards SDGs

Notes: PjBL= Project-based Learning; PBL= Problem-based Learning; IBL=Inquiry-based Learning; DBL= Digital-based Learning

Project-Based Learning (PjBL)

Project-Based Learning (PjBL) emerges as the most holistic teaching strategy in this study, seamlessly integrating elements of PBL, DBL, and IBL while emphasizing real-world problem-solving, collaboration, and sustainability. Janhonen et al. (2023) demonstrated how students actively co-developed sustainable school meals in their home economics education, fostering collaboration among peers, teachers, and food managers while enhancing practical and evaluative skills. Similarly, Bettencourt et al. (2023) highlighted PjBL's impact through student-led beach clean-ups, where learners proposed measures to combat marine litter, gaining a deeper understanding of its sources and impacts. Hands-on activities, such as observing microplastics, further strengthened their environmental awareness.

Abdurrahman et al. (2023) unveiled how integrating engineering design processes into PjBL enhanced students' systems thinking as they tackled real-life environmental issues like designing renewable energy solutions. Likewise, Rahmawati et al. (2022) integrated ethical dilemmas within STEAM projects, empowering students to engage in critical reflective thinking, collaborative problem-solving, and environmental advocacy. These findings align with Linkwitz & Eilks (2022), who demonstrated the integration of green chemistry concepts through projects like "From sugar beet to bioplastics," fostering environmental awareness and practical chemistry education over an extended period.

Further supporting PjBL's efficacy, Paaske et al. (2021) and Vare (2021) highlighted action-oriented learning through student-led sustainability projects. These projects promoted teamwork, community involvement, and ecological awareness, cultivating student agency and innovative thinking. Similarly, Bentz (2020) emphasized the role of experiential learning in climate change education, where students connected personal insights with broader themes through art-based projects, enhancing their understanding of

sustainability. Ian et al. (2019) also emphasized experiential learning, empowering students to collaborate on sustainable development plans, fostering teamwork, and inspiring action.

Other studies, such as Derler et al. (2020) and Berman (2021), showcased the integration of PjBL into food literacy and environmental sustainability initiatives. Derler's work involved collaborative development of sustainable food products, while Berman's study highlighted projects like tree planting and recycling, which enhanced environmental responsibility. Collectively, these studies underscore PjBL's adaptability across contexts, its ability to foster critical thinking, collaboration, and environmental stewardship, and its effectiveness in preparing students to address global sustainability challenges with confidence and innovation.

Digital-Based Learning (DBL)

Digital-based learning (DBL) effectively integrates technology into education, enabling students to gain conceptual understanding and technological proficiency. Syskowski et al. (2024) highlighted the use of tablets and Augmented Reality (AR) in chemistry education to create immersive and sustainable learning environments, emphasizing self-regulated learning. Similarly, Li et al. (2022) showcased how Web GIS transformed geography education by improving natural disaster learning and alleviating teachers' technical burdens. Both studies underscore the use of digital tools to enhance students' independent learning and conceptual understanding of complex systems, such as environmental processes in chemistry and geography.

DBL also fosters global collaboration and intercultural awareness. Lochner et al. (2021) explored Virtual School Garden Exchanges (VSGEs), where students used digital platforms to share school garden projects with peers worldwide. This collaboration promoted critical thinking, empathy, and global citizenship while challenging stereotypes. Similarly, Georgousis et al. (2021) utilized a fully ICT-supported DBL approach to connect students with geoheritage and cultural values through inquiry-based learning strategies. Both studies highlight how DBL encourages students to think critically and engage with diverse perspectives. These findings demonstrate the versatility of DBL in cultivating social and intellectual competencies.

The use of serious games in DBL has proven effective in promoting environmental awareness and sustainability. Janakiraman et al. (2021) reported that the EnerCities game improved students' attitudes toward energy conservation, recycling, and resource management, fostering pro-environmental behaviors. Similarly, Koenigstein et al. (2020) and Neset et al. (2020) emphasized how serious games enhanced students' understanding of climate adaptation and marine sustainability through systems thinking and role-playing activities. Across these studies, serious games provided engaging platforms for students to connect personal experiences with environmental issues, reinforcing the role of DBL in cultivating sustainability-oriented mindsets.

Problem-Based Learning (PBL)

Problem-based learning (PBL) has been widely recognized for its effectiveness in fostering hands-on, contextual problem-solving skills among students. Saragih et al. (2021) emphasized how PBL enhances problem-solving in sustainability-oriented biology lessons, preparing students to address environmental and social responsibilities through critical skills like problem identification, questioning, and developing solutions. Similarly, Istiana et al. (2021) clarified the integration of marine education with natural science learning, promoting environmental awareness and fostering an understanding of coastal ecosystems among students and local communities.

Furthermore, Eugenio-Gozalbo et al. (2022) showcased the societal benefits of garden-based teaching on sustainable diets, where students engaged in activities like analyzing food labels and visiting markets to explore food sustainability issues. Collectively, these studies underscore PBL's effectiveness in integrating sustainability into education, enhancing systemic thinking, environmental awareness, and collaborative problem-solving skills among learners.

Inquiry-Based Learning (IBL)

Gutierrez et al. (2024) demonstrated how IBL workshops enhanced secondary school students' attitudes toward botany by incorporating local knowledge and traditional practices with aromatic plants. This

experiential approach encouraged students to apply the scientific method formulating hypotheses, conducting observations, and drawing conclusions while promoting sustainable resource management. Similarly, Zidny et al. (2021) integrated indigenous and Western scientific perspectives in chemistry education, helping students connect theoretical knowledge with practical, socio-scientific issues through tasks such as worksheets, videos, and articles. Both studies highlight IBL's impact on improving scientific understanding, sustainability awareness, and active student engagement through inquiry-driven activities.

The effectiveness of these strategies varies significantly across cultural and educational contexts. PjBL's success in collectivist settings like Finland (Janhonen et al., 2023) and Indonesia (Rahmawati et al., 2022) stems from its alignment with communal learning traditions, while DBL's adaptability makes it particularly valuable in technology-rich environments with decentralized education systems (Syskowski et al., 2024; Li et al., 2022). Developing countries can adapt Germany's Virtual School Garden model (Lochner et al., 2021) by pairing digital tools with localized content, as demonstrated in the geoheritage studies (Georgousis et al., 2021). Three key policy actions emerge: (1) Ministries should mandate teacher training in PjBL and DBL integration, following Austria's food literacy model (Derler et al., 2020); (2) Schools need protected time for sustainability projects like Portugal's beach clean-ups (Bettencourt et al., 2023); and (3) Governments must fund localized digital resources, mirroring Indonesia's STEM-EDP successes (Abdurrahman et al., 2023). These measures would operationalize the UNESCO (2020) framework while addressing contextual barriers identified in the studies.

3. Barriers and Challenges in Integrating ESD in Secondary Schools

In our thorough examination of 23 articles, 12 studies specifically discuss the barriers and challenges of integrating Education for Sustainable Development (ESD) into secondary schools. These studies collectively unveiled a complex web of obstacles that significantly hinder the smooth integration of sustainability concepts in secondary education. However, they also highlighted how researchers and educators have sought to overcome these challenges, offering valuable insights for future implementation.

One recurring challenge that stands out as a significant barrier to effective ESD integration is the insufficient training of teachers (Istiana et al., 2021; Georgousis et al., 2021). Istiana et al. (2021) stress the need for teachers to acquire competencies, emphasizing the crucial role of comprehensive training programs. Similarly, Georgousis et al. (2021) shed light on challenges in evaluating program success, particularly regarding students' empowerment goals related to geoheritage values. To address this, studies have proposed targeted professional development workshops and competency frameworks tailored to ESD, ensuring teachers are equipped with both general and program-specific skills.

Another significant challenge highlighted in the literature revolves around the lack of teaching materials for ESD (Koenigstein et al., 2020; Neset et al., 2020; Zidny et al., 2021). Koenigstein et al. (2020) emphasize the absence of learning tools for teaching ocean systems, while Neset et al. (2020) stress the need for materials in high school education. Zidny et al. (2021) further underscore the overarching need for learning materials implementing ESD. To overcome this, researchers have developed context-specific resources, such as digital platforms and interdisciplinary toolkits, to bridge the gap and provide educators with accessible, high-quality materials.

A prevalent challenge identified is the insufficient understanding of how to implement ESD in the classroom (Rahmawati et al., 2022; Bettencourt et al., 2023; Bentz, 2020; Abdurrahman et al., 2023). These studies call for transformative learning experiences (Rahmawati et al., 2022) and recognize the ineffectiveness of traditional learning approaches in the modern era (Abdurrahman et al., 2023). For instance, Abdurrahman et al. (2023) showcased how integrating engineering design processes into project-based learning (PjBL) enhanced students' systems thinking, providing a practical model for overcoming implementation challenges. Similarly, Bettencourt et al. (2023) advocate for educational interventions that align with local contexts, while Bentz (2020) highlights the need for effective strategies in addressing climate change, demonstrating the importance of context-specific approaches.

The preference for teaching subject-specific content over adopting a cross-disciplinary approach emerges as another significant challenge (Janhonen et al., 2023; Bentz, 2020). Both studies highlight

the power and responsibility of teachers in organizing learning spaces and the potential limitation of students' participatory opportunities across disciplines. Janhonen et al. (2023) emphasize the role of teachers in fostering interdisciplinary collaboration, while Bentz (2020) discusses stereotypes in art education, indicating the need for context-specific strategies. To address this, researchers have proposed collaborative teaching models and interdisciplinary curricula that encourage holistic learning experiences. In conclusion, our synthesis of these themes underscores the intricate challenges in integrating ESD in secondary schools as shown in Figure 3. However, the studies also highlight innovative strategies to overcome these barriers, such as targeted teacher training, the development of context-specific teaching materials, transformative learning approaches, and interdisciplinary collaboration.

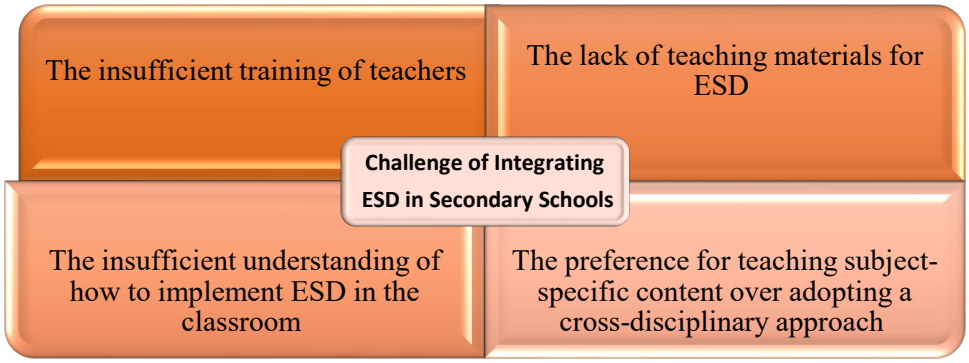

Figure 3. The challenge of Integrating ESD

Conclusion

In summary, this systematic review provides a comprehensive analysis of diverse teaching strategies aimed at integrating Education for Sustainable Development (ESD) into secondary schools. Prominent methodologies such as Problem-based Learning (PBL), Digital-based Learning (DBL), Project-based Learning (PjBL), and Inquiry-based Learning (IBL) were identified, showcasing their effectiveness in fostering sustainability education and equipping students with the skills and knowledge needed to address pressing global challenges. The review also highlighted the outcomes of these strategies, emphasizing their potential to cultivate critical thinking, creativity, and a sense of responsibility toward sustainability. However, the identification of challenges and barriers such as insufficient teacher training, lack of teaching materials, and the preference for subject-specific over interdisciplinary approaches underscores the need for context-specific solutions. Addressing these obstacles is essential to ensure the successful implementation of ESD in diverse educational settings. To advance the field of Education for Sustainable Development (ESD), future research must prioritize four critical areas. First, rigorous investigation into innovative teaching methodologies such as gamified learning, immersive technologies, and community-based pedagogies can uncover new pathways for integrating ESD principles in secondary education. Second, longitudinal studies on professional development models are needed to establish evidence-based frameworks for enhancing teacher competencies, particularly in under-resourced regions where ESD implementation remains challenging. Third, the establishment of global collaborative platforms would facilitate the exchange of best practices, allowing educators to adapt proven strategies like Finland's collaborative PjBL model or Germany's virtual exchange programs to their local contexts. Such platforms should emphasize peer-reviewed case studies, open educational resources, and policy briefs tailored to different educational systems. Finally, future efforts must focus on developing adaptable ESD materials that accommodate diverse classroom realities. This includes creating modular lesson plans for interdisciplinary sustainability projects, low-cost digital tools for schools with limited infrastructure, and assessment rubrics that measure both cognitive and behavioral outcomes. By addressing these priorities, the academic community can bridge persistent gaps between ESD theory and practice, ultimately empowering secondary schools worldwide to cultivate generations of sustainability literate citizens equipped to tackle 21st-century challenges. This expanded research agenda will not only refine pedagogical approaches but also inform policy decisions, ensuring ESD's transformative potential is realized across all educational settings.

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