



# Toward Sustainability: Evaluating ESD Implementation in K-12 Schools: A Systematic Review



Vol. 10, No. 01, 2025, Page: 58-79

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## Abstract

This systematic review evaluates 30 peer-reviewed articles published between 2015 and 2025, using the PRISMA method. The implementation methods are categorized into five groups: Classroom-Based Implementation (n = 10), Project-Based and Experiential Learning (n = 3), Textbook and Curriculum-Based Implementation (n = 3), School Infrastructure and Leadership (n = 3), and Extracurricular and Global Initiatives (n = 11). Classroom-based approaches are the most widely applied, featuring strategies such as transdisciplinary teaching and outdoor learning. A significant barrier identified across the literature is the lack of teacher preparedness and limited access to professional development (reported in 18 studies), alongside challenges such as insufficient institutional backing and resource limitations. This review presents a comprehensive typology of ESD implementation methods in K-12 settings, highlighting underrepresented areas such as leadership and structural integration. Mapping the distribution and frequency of implementation strategies provides a clearer understanding of current practices and gaps. In response, the review proposes actionable recommendations to improve ESD delivery, emphasizing the need for comprehensive teacher training, innovative curriculum approaches, and coordinated efforts across educational and community sectors to foster meaningful and sustainable learning outcomes.

## Keywords:

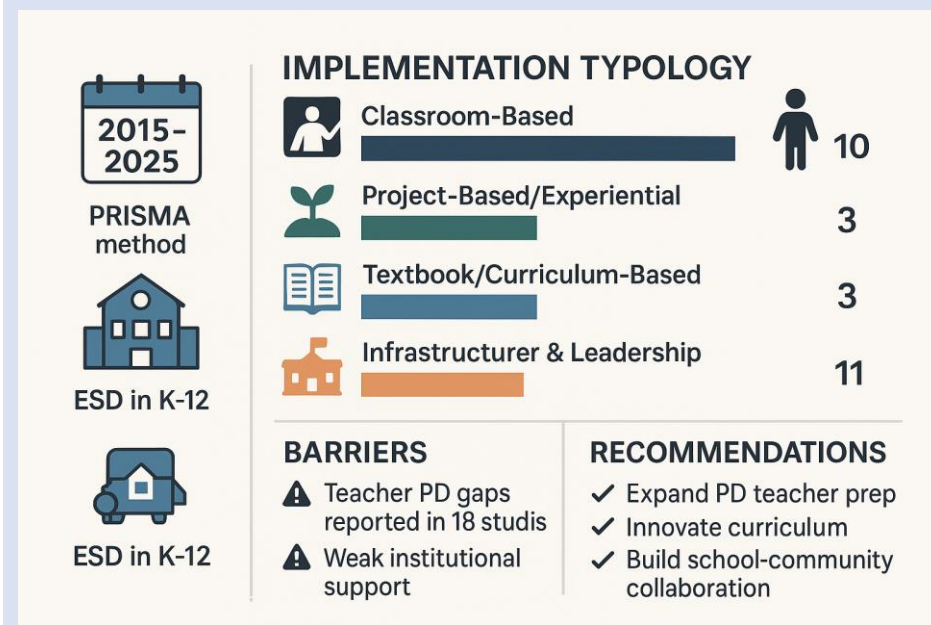
Sustainability;  
ESD; K-12 School

Submitted: May  
2025

Revised: June  
2025

Accepted: July  
2025

## Graphical Abstract



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## Introduction

The Sustainable Development Goals (SDGs), also known as the Global Goals, were established by the United Nations in 2015 to address poverty, protect the planet, and promote peace and prosperity worldwide by 2030. Consisting of 17 goals and 169 interconnected indicators, the SDGs aim to balance economic, social, and environmental aspects of sustainable development (Caballero, 2019). Within this framework, education holds a central position. Specifically, SDG 4 emphasizes "ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all," with Target 4.7 calling for all learners to acquire the knowledge and skills needed to promote sustainable development by 2030 (Muhamoud et al., 2020). This target highlights the importance of embedding sustainability principles across educational systems to prepare learners to make informed decisions and contribute responsibly to society (Cebrián & Junyent, 2015; Kioupi & Voulvoulis, 2019).

Education for Sustainable Development (ESD) is widely recognized as a critical mechanism for realizing these ambitions. ESD plays a pivotal role in achieving these goals by promoting changes in knowledge, skills, perspectives, and behaviors necessary for a sustainable future (Agbedahin, 2019; Dambudzo, 2015). However, implementing ESD in practice remains a complex undertaking. Research has shed light on efforts to integrate sustainability principles into curriculum and pedagogy, but challenges persist including the dominance of exam-oriented systems and the difficulty of shifting toward more transformative educational models (Kieu et al., 2016). Cross-national studies have revealed diverse implementation strategies, enabling cross-contextual learning and reflection (Fredriksson et al., 2020). The role of school leadership has also emerged as crucial, with leaders navigating dilemmas in introducing new sustainability-oriented visions and practices (Abidin et al., 2023a).

Moreover, successful implementation requires systemic coordination—spanning governance structures, forward-looking education policies, and robust support for teachers through professional development and mentoring programs (Beltran et al., 2013; Kang, 2019). Teachers play a decisive role in realizing ESD goals in the classroom, as their capacities and attitudes significantly influence how sustainability is interpreted and taught (Inayah et al., 2022). These efforts are particularly vital in early childhood and teacher education contexts (Bascopé et al., 2019).

Despite growing momentum, various challenges persist. Studies report obstacles such as insufficient teacher preparation, curriculum rigidity, and lack of contextual relevance, which hinder effective implementation (Veckalne & Tambovceva, 2022). Nevertheless, promising classroom experiences have shown that ESD-based learning can foster student awareness, problem-solving, and critical thinking, while reinforcing environmental and social responsibility (Mufida et al., 2018; Violanda et al., 2023).

While the existing literature offers valuable insights into specific components of ESD such as curriculum design, teacher preparation, or leadership, few studies provide a comprehensive synthesis of the diverse strategies used to implement ESD at the K–12 level. Furthermore, the interconnected challenges that influence implementation across different educational settings, including structural, institutional, and cultural barriers, are often insufficiently

addressed. This lack of integration limits our understanding of what enables or constrains effective ESD in schools.

Accordingly, a systematic review is needed to consolidate recent findings, map the methods through which ESD is enacted in K–12 education, identify persistent obstacles, and offer recommendations to inform future practice and policy. This study seeks to fill that gap by addressing the following research questions:

RQ1: What implementation methods of ESD are used in K–12 schools?

RQ2: What are the limitations of these implementation methods?

## Method

This research employs the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) reporting model to identify existing studies on the implementation of ESD on K-12 schools. PRISMA is a guideline developed as an evolution of the QUOROM guideline to enhance the reporting of systematic reviews and meta-analyses (Liberati et al., 2009). By using PRISMA ensures methodological and transparent review process, enhancing the quality of reporting (Page, Moher, et al., 2021). This analysis includes perspectives from students, teachers, and stakeholders such as school principals and administrative staff on the methods and strategies used in implementing ESD at the K-12 Level, as well as any limitations. The PRISMA flow diagram is shown in Figure 1.

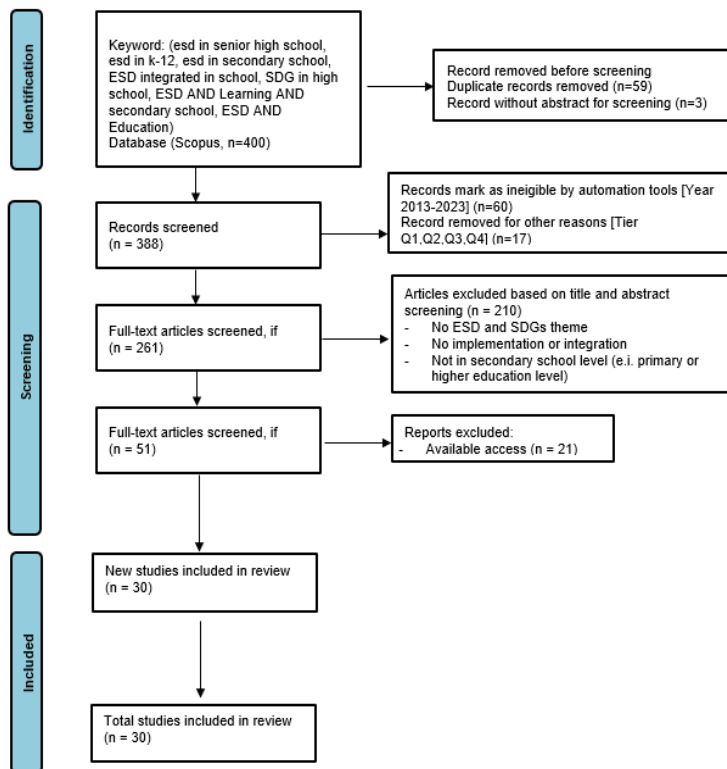


Figure 1. PRISMA Flowchart

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## Identification Phase

The PRISMA framework involves several key phases, including the identification, screening, and inclusion phases, which are crucial for the selection and inclusion process of studies in a systematic review (Trapani et al., 2021). The author utilized the Scopus database for this review as it provides access to high-quality journals across multiple disciplines and applies rigorous indexing standards, thereby ensuring the academic credibility of the included sources (Elsevier, 2024). Its structured indexing also supports transparency and reproducibility, which are essential in systematic reviews (Page et al., 2021). The systematic review conducted in this study synthesizes relevant articles using the Watase UAKE application ([watase.web.id](http://watase.web.id)), an online tool developed to facilitate research collaboration and structured literature analysis. This platform extracts data from webpages directly linked to Scopus, enabling the identification and classification of literature based on defined research parameters. The search and sorting of articles were conducted using the Watase UAKE website covering the period from 2015 to 2025 and Scopus quartiles Q1–Q4. The literature selection process follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure methodological transparency and rigor. Watase UAKE is specifically designed to support researchers especially those in academic and postgraduate contexts in performing systematic literature reviews, model development, gap analysis, and research planning (Wahyudi, 2024). The focus was on ESD articles at the K-12 education level, excluding higher education. Keywords related to ESD and K-12 School were used, along with terms such as SDGs, primary school, and secondary school. The search results on the Watase website are presented in Table 1.

**Table 1.** Keywords and Number of Obtained Articles

No.	Keywords	Number of Articles
1.	ESD in in K-12	7
2.	ESD in Primary School	10
3.	ESD in secondary school	94
4.	ESD integrated in school	80
5.	SDGs implementation in school	80
6.	ESD AND learning AND K-12 school	41
7.	ESD AND education	88
	Total	400

## Screening Phase

The initial Scopus search resulted in 400 articles. After excluding 59 articles that appeared under multiple and 3 articles without abstracts, the total number of articles was reduced to 388. These articles, will be further filtered based on the criteria outlined in Table 2.

**Table 2.** Inclusion & Exclusion Criteria

<b>Criteria</b>	<b>Inclusion Criteria</b>	<b>Exclusion Criteria</b>
Article title and content	an appropriate title that complied with the study's requirements	did not match the requirements of the study and had an irrelevant title
Year of publication	Research conducted between 2015-2025	Research conducted outside the timeframe of 2015-2025
Language	Articles written in English	Articles written in languages other than English
Type of publication	Solely for journal articles indexed in Scopus (Q1, Q2, Q3 and Q4)	Review articles, editorial opinions, book chapters, news articles, or articles without Scopus indexing or journal rankings not clearly stated (non-Q1 to Q4)
Field of article study	Science education	Other than science education
Educational context	K-12 school	Higher education (universities) or non-formal education
Accessibility	Full-text articles or open access	Preview and required payment

After applying inclusion and exclusion criteria, 261 articles were identified for review based on titles, abstracts, and keywords. Only articles focusing on the implementation of ESD, SDGs, or environmentally based education for K-12 school students were selected, resulting in 51 relevant articles. These selected articles were assessed for reliability by two raters who had agreed upon inclusion criteria to ensure consistency. Inter-rater reliability was measured using Cohen's kappa coefficient, which ranges from -1 to +1. The kappa coefficient between the two raters was 0.8, which falls into the substantial category according to Belur et al., (2018). Finally, the articles were further filtered based on accessibility, leading to a final set of 30 articles for inclusion in this literature review.

### Data Analysis

Data from the 30 selected articles were systematically extracted using a data matrix format. The matrix captured details such as Author(s) and year, Target population (e.g., students, teachers, principals), Implementation methods and educational strategies, Reported results, and limitations or challenges. Each article was coded according to these elements, and themes were identified based on recurring approaches to ESD implementation. Articles were grouped into thematic categories (e.g., classroom-based, project-based, textbook integration), facilitating comparative analysis across contexts. The data were then synthesized narratively by focusing on the problem formulation and research objectives: i) Identifying the implementation methods of Education for Sustainable Development (ESD) in K-12 schools, and (ii) Analyzing the limitations of these implementation methods. The synthesis yields conclusions and recommendations regarding current ESD implementation practices in K-12 education.

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## Results & Discussion

The implementation of Education for Sustainable Development (ESD) is crucial for addressing the challenges of sustainable development and laying the groundwork for a future characterized by sustainability (Pauw et al., 2015). The need to incorporate ESD into all levels of education, including primary and secondary education, underscores the importance of integrating sustainability principles across various subjects and disciplines (Ntsiful et al., 2023). Comparative studies of ESD curricula in high schools across different countries emphasize the importance of examining and comparing ESD policies and practices, demonstrating the global significance of ESD in secondary education (Fredriksson et al., 2020).

### ESD Implementation Methods on K-12 Schools:

The implementation of the methods can vary in scale from small to large. In this study, a total of 30 studies were reviewed and classified into five implementation categories: Classroom-Based (n = 10), Project-Based and Experiential Learning (n = 3), Textbook and Curriculum-Based Implementation (n = 3), School Infrastructure and Leadership (n = 3), and Extracurricular and Global Initiatives (n = 11). Each category illustrates unique strategies for implementing ESD across K-12 schools, which are further elaborated below.

#### *Classroom-Based Implementation*

Classroom-based implementation is the most widely documented method in the reviewed literature. This approach typically involves integrating ESD principles into everyday lessons across subjects, allowing teachers to adapt sustainability topics to existing curricula with minimal structural modifications. Various pedagogical strategies, including transdisciplinary learning, outdoor activities, and sociocritical approaches, have been employed to engage students in meaningful sustainability education within the classroom setting. Table 3 presents studies categorized under this implementation type, highlighting the methods employed and the focus of each intervention.

**Table 3.** Classroom-based implementation methods

Author	ESD Implementation Methods
Suárez et al.,	Integrating EE topics into learning
Jeziorski et al.,	Transformative-sociocritical approach
Manni	Outdoor learning, social sustainability projects, and play-based learning
Nordén	Transdisciplinary learning with a global dimension
Sund & Gericke	Cross-curricular learning
Waltner et al.,	Teaching with ESD-related topics
Nguyen	Integrating the Circular Economy in STEM
Li & Eilks	Integrating Confucian ecological ethics in chemistry education
Munasi	Field trips, visual aids, and practical demonstrations
Silva et al.,	Ocean literacy and sustainable consumption education

A key strategy for promoting ESD is to integrate sustainability concepts into classroom settings. This involves incorporating sustainability topics into educational content, such as

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Environmental Education (EE) programs. For example, in Boyacá, Colombia, Suárez et al. (2023) implemented EE programs that cover water resource conservation and the protection of fauna and flora. Similarly, Jeziorski et al., (2023) and Silva et al., (2024) studied sustainability education through the Seine River and sustainable fish consumption, respectively. These initiatives align with SDGs such as clean water and sanitation (SDG 6), biodiversity and terrestrial ecosystem conservation (SDG 15), and responsible consumption and production (SDG 12).

By integrating these themes into education, schools promote environmental awareness and conservation behavior, fostering active participation from teachers, students, and the community to achieve sustainability goals (SDG 17). Moreover, environmental-based learning approaches not only raise sustainability awareness but also reduce student fatigue and foster a deeper affection for nature (Subandi et al., 2017). Collectively, these examples demonstrate that contextualized, locally relevant EE programs can cultivate student engagement and support pro-environmental behaviors. However, to maximize impact, such initiatives should be accompanied by systemic pedagogical planning that ensures continuity, reflection, and active community involvement.

Jeziorski examines how students in France understand and interact with sustainability issues related to the Seine River, as well as how the local context influences their engagement as eco-citizens. The study highlights that students value experiential and contextually relevant educational approaches more than traditional school formats. Similarly, Silva et al. studied the effects of educating 4th-grade students about sustainable fish consumption, evaluating its efficacy in teaching key sustainability concepts, including fish biodiversity, fishing techniques, minimum catch sizes, closed fishing seasons, and food labeling. The findings revealed a significant improvement in students' awareness and willingness to adopt more sustainable consumption practices. This supports the goal of promoting environmental awareness and responsible consumption (SDG 12) while reinforcing the role of early education in fostering pro-environmental behaviors.

Embedding sustainability concepts into learning materials enhances student exposure to environmental and social issues, fostering interdisciplinary and transdisciplinary learning. Manni, (2023) discusses the School-Age Educare (SAEC) model as a transdisciplinary approach, while Sund & Gericke, (2020) explore cross-curricular ESD in Sweden, and Nordén, (2018) delves into transdisciplinary teaching in development projects. Manni (2023) highlights the crucial role of SAEC in ESD through a transdisciplinary approach that goes beyond the limitations of the formal school curriculum. ESD practices within SAEC encompass traditional outdoor environmental education, a local-global social perspective, and a creative, participatory, and play-based method. Sustainability learning in SAEC is more effective when conducted through direct experiences and active engagement, allowing students not only to understand sustainability issues but also to explore real and imaginative action choices. These transdisciplinary approaches offer valuable insights into holistic learning experiences, demonstrating how flexibility in content and pedagogy can broaden the scope of sustainability education.

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Nordén (2018) explored the experience of transdisciplinary teaching in educational development projects and found a reciprocal connection between teachers' sense of ownership and their capacity to redesign strategies and practices. When teachers claimed ownership of the project, the subject matter naturally adopted a transdisciplinary framework. Conversely, when teachers saw their role as merely assisting, they tended to be overwhelmed by existing challenges. This highlights a crucial pedagogical implication: empowering teachers as co-creators rather than passive implementers enhances the transformative potential of ESD.

In an interdisciplinary study, Sund and Gericke (2020) demonstrated that cross-curricular collaboration in ESD enhances the effectiveness of sustainability education by showing how different subjects can complement each other. However, the success of such interdisciplinary learning depends on educators' ability to bridge disciplinary boundaries and create meaningful connections between sustainability concepts. Furthermore, (2020) found that teachers often cover more ESD topics in classrooms than they are familiar with, such as SD, ESD, or UN DESD/WAP. This indicates that teachers' environmental awareness can drive the integration of sustainability-related content, even without extensive familiarity with academic ESD terminology.

Interdisciplinary and transdisciplinary approaches also support effective pedagogical strategies for sustainability education. Munasi, (2024) identified various teaching strategies in ESD, including experiential methods such as field trips, visual aids, and practical demonstrations, which enhance student engagement in sustainability issues. In STEM education, Nguyen, (2023) found that integrating the Circular Economy (CE) into ESD through constructivist-based teaching helps students connect sustainability concepts to real-world contexts. (2020) emphasize that CE education is grounded in outcome-based curriculum development and constructivist teaching methods, key pedagogical approaches in STEM education. These methods integrate knowledge, skills, and values from science, technology, engineering, and mathematics to solve real-life problems, enhancing students' abilities to apply interdisciplinary understanding in meaningful contexts. This approach encourages educators to transcend disciplinary boundaries while maintaining subject-specific expertise, fostering a comprehensive and integrated educational strategy.

Cultural perspectives in ESD can further enrich student learning. Li & Eilks, (2024) found that integrating Confucian Ecological Ethics (CEE) into chemistry education in China enhanced students' environmental awareness and helped them recognize the intersection of science and cultural values. Their research highlights how incorporating both pedagogical and cultural strategies into ESD can create a more holistic learning experience, bridging theoretical knowledge with real-world sustainability challenges. By incorporating both pedagogical and cultural strategies, ESD can be further enriched to provide students with a comprehensive, multidimensional learning experience through hands-on learning experiences.

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### ***Project-Based and Experiential Learning***

Project-based and experiential learning approaches provide students with opportunities to apply sustainability concepts through active, real-world engagement. These methods emphasize collaboration, inquiry, and contextual learning, making them valuable in fostering critical thinking and environmental responsibility. Table 4 outlines several studies that illustrate how these approaches have been implemented in K–12 education.

**Table 4.** Project-Based and Experiential Learning Implementation Methods

<b>Author</b>	<b>ESD Implementation Methods</b>
Loinaz et al.,	ERASMUS+ project (CS4ESD)
Sass et al.,	Action-oriented approach and VALIES Project
Linkwitz & Eilks	Action Research Project

Beyond traditional classroom instruction, hands-on and project-based learning approaches engage students in active sustainability practices. These approaches enhance problem-solving skills and encourage student participation in sustainability initiatives. By engaging in project-based learning, students move from theoretical discussions to real-world applications, reinforcing sustainability principles in a meaningful way. For example, (2022) found that Green Chemistry (GC) lesson plans improved student understanding and motivation, while Sass et al. (2023) demonstrated that Action Competence in Sustainable Development (ACiSD) enhanced self-efficacy in sustainability actions. This action-oriented learning complements interdisciplinary classroom approaches by encouraging students to implement sustainability practices in real-world applications. This direct engagement empowers students to take ownership and develop a deeper sense of responsibility towards sustainability. Green Chemistry (GC) is particularly effective in this regard as it offers innovative scientific solutions to global environmental challenges (Mitarlis et al., 2017), providing students with practical examples of how scientific knowledge can address pressing sustainability challenges. Furthermore, Loinaz et al., (2024) found that the CS4ESD project in Greece, the UK, and Spain demonstrated that Citizen Science improves sustainability competencies and student engagement. These studies highlight the value of citizen science as a complementary approach to textbook-based learning methods, bridging scientific knowledge with real-world applications. By combining action-based learning with citizen science projects, students develop sustainability competencies and actively contribute to environmental research with tangible community impacts.

### ***Textbook and Curriculum-Based Implementation***

Following the exploration of project-based and experiential learning strategies, another significant direction in ESD implementation is the integration of sustainability principles into textbooks and formal curricula. This approach promotes consistency and coherence in ESD delivery by embedding sustainability themes into established educational frameworks. Table 5 below presents studies that exemplify this curriculum-based implementation.

**Table 5.** Textbook and Curriculum-Based implementation methods

<b>Author</b>	<b>ESD Implementation Methods</b>
Koutalidi et al.,	School projects intervening with the Educational Activity Guide on Biogeochemical Cycles
Liao & Chang	Slow Fish Movement (SFM) Curriculum
Koutalidi & Scoullou	Educational Activity Guide on Biogeochemical Cycles
Mogren & Gericke	Transformative perspective approach

The structured inclusion of ESD in textbooks and national curricula provides a systematic foundation for sustainability education. This approach ensures that sustainability concepts are consistently reinforced throughout students' academic journeys and complements hands-on learning experiences with theoretical depth. Koutalidi & Scoullou, (2016) developed new didactic materials for the carbon, nitrogen, phosphorus, sulfur, and water biogeochemical cycles tailored to Greek secondary schools. The analysis of experimental implementation results showed a positive impact on students' knowledge. Students were able to minimize misunderstandings, better understand the cycles, and grasp their connection to various aspects of sustainable development, such as the relationship between climate change and disruptions in the water cycle, issues of overpopulation and hunger related to agricultural production needs, natural resource use, and fertilizer use linked to the nitrogen and phosphorus cycles.

Furthermore, (2016) conducted a study in which they implemented various teaching methods, including brainstorming, conceptual mapping, experiments, simulations, models, constructions, dramatization, and field activities, in urban and special education areas using textbooks. The intervention was successful, significantly improving students' knowledge and attitudes across different levels.

Similarly, and Chang (2021) demonstrated that integrating sustainability themes into subject-specific curricula, such as the Slow Fish Movement, significantly improved students' understanding and attitudes toward Marine Environment Conservation (MEC) and Marine Resource Sustainability (MRS). This case illustrates how a well-designed, context-specific curriculum can foster both cognitive and affective learning outcomes in ESD. However, when compared with other curriculum-based initiatives, such as Silva et al., (2024), which focused on sustainable fish consumption among younger learners, a pattern emerges: subject-integrated sustainability education can be highly effective, particularly when aligned with students' everyday experiences and local environmental issues. Yet, questions remain regarding the long-term sustainability of these learning outcomes. Few studies, including that of Liao & Chang, provide follow-up data to assess whether improved awareness and attitudes are sustained over time or translated into consistent pro-environmental behavior.

To strengthen the effectiveness of curriculum-based approaches in ESD, future research should consider longitudinal assessments and comparative analyses across different contexts and age groups. Doing so would help determine which design elements, such as cultural relevance, experiential learning, or interdisciplinary integration, most strongly influence lasting sustainability competencies. Beyond subject-specific curricula, Mogren & Gericke, (2017) studied transformative education in active ESD schools in Sweden, highlighting the

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use of school-wide strategies to engage students with sustainability issues. Their findings suggest that incorporating transformative learning approaches into educational programs can enhance sustainability education beyond theoretical knowledge.

Textbooks play a crucial role in ESD by complementing classroom and hands-on learning activities. They provide a structured approach to learning sustainability concepts, facilitating a deep understanding that can be applied in real-world scenarios. By integrating sustainability principles into subject-specific curricula and adopting transformative educational approaches, schools can systematically enhance sustainability education, ensuring a balance between theoretical knowledge and practical application.

### ***School Infrastructure and Leadership in ESD***

The implementation of ESD is not solely reliant on pedagogical methods but is also deeply influenced by the structural and managerial dimensions of a school. Leadership practices, institutional vision, and infrastructural support form the foundation upon which sustainable education can be meaningfully embedded. Table 6 summarizes studies that illustrate how school infrastructure and leadership contribute to the implementation of ESD in K-12 education.

**Table 6.** School Infrastructure and Leadership Implementation Methods

<b>Author</b>	<b>ESD Implementation Methods</b>
Ntsiful et al.,	Partnership-Relationship Model between school libraries and SDG 4
Osanai & Yu	Research Activities on SDGs
Maqbool et al.,	Leadership-driven educational transformation

The implementation of sustainability practices in school infrastructure and leadership further supports ESD beyond traditional classroom instruction. These aspects play a crucial role in creating a conducive environment for sustainability education and reinforcing a school-wide commitment to sustainable practices. For example, a study by Ntsiful et al., (2023) highlighted how school libraries in Ghana support SDG 4 by providing sustainability-related resources. Consistent with this perspective, Osanai & Yu, (2023) emphasized the importance of research initiatives that integrate sustainability topics into school activities to cultivate students' sustainable mindsets. School infrastructure initiatives provide students with resources and opportunities to engage with sustainability topics, complementing classroom learning and extracurricular activities. In addition to teaching methods and infrastructure, the effectiveness of ESD implementation is significantly influenced by leadership styles. Maqbool et al., (2024) found that innovative leadership approaches such as leadership empowerment, inspiring learners, resilient vision, and transformational leadership positively impact the achievement of SDGs in secondary education in Pakistan. These leadership styles enhance student engagement, foster a sustainability-oriented mindset, and create a more effective learning environment to support SDG-focused education.

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### ***Extracurricular and Global Initiatives***

Another important avenue for implementing ESD lies in extracurricular and globally connected initiatives. These programs extend sustainability education beyond the confines of the formal classroom by engaging students in hands-on, community-oriented, or internationally collaborative activities. Table 7 highlights several studies that reflect this approach as shown in Table 3.

**Table 7.** Extracurricular and Global Initiatives Implementation Methods

<b>Author</b>	<b>ESD Implementation Methods</b>
Müller et al.,	ESD implementation through lessons, projects, school farms, and expert visits
Fredriksson et al.,	School A: lessons, group projects; School B: lessons and workshops; School C: school projects; School D: science projects
Garner et al.,	SLs Project (Sustainability and Chemistry in Non-formal Student and Laboratories)
Berman	Ecoliteracy teaching integrated with tourism
Scharenberg et al.,	ESD practice in learning, "Fridays for Future" initiative
Lochner	Virtual School Garden Exchange (VSGE)
Ian et al.,	Young Persons' Plan for the Planet (YPPP) Program
Verachtert & Stiers	VALIES Project
Yuan et al.,	Green School Program
Schauss & Sprenger	Climate Change School Project

Extracurricular programs and international collaborations enhance student engagement with sustainability topics beyond the formal educational setting. These initiatives provide students with exposure to real-world sustainability challenges and foster global cooperation. Schools in countries such as Japan, Sweden, Kenya, and Germany integrate Education for Sustainable Development (ESD) into their curricula through interdisciplinary projects and student-led research (Berman, 2021; Fredriksson et al., 2020; Müller et al., 2022).

A comparative study conducted by (2020) examined the implementation of ESD in Sweden and Japan. In Sweden, one school introduced a subject called "Global Life" where students researched local sustainability issues and presented their findings, emphasizing the connection between regional and global sustainability. Another school in Sweden has adopted project-based learning, incorporating themes such as "Migration" and "Global Health," which allows students to engage deeply with sustainability issues. In Kenya as observed in Berman's, (2021) research, schools are implementing sustainability initiatives such as using solar power, rainwater harvesting, eco-friendly farming practices, and energy-efficient stoves to raise awareness about sustainability through hands-on projects. On a policy level, Müller et al., (2022) compared ESD implementation in the US, China, and Germany. Germany stands out for prioritizing ESD in national education policies by integrating it into mandatory curricula. In contrast, the US and China view ESD primarily as an extracurricular activity due to the lack of national mandates. This underscores the importance of institutional support in determining the depth to which sustainability education is embedded within school systems.

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Several global initiatives contribute to ESD implementation through curriculum integration, teacher training, and experiential learning. The Valorization of Integrated and Action-Oriented Education for Sustainable Development (VALIES) project focuses on equipping teachers with ESD methodologies. Research shows a significant improvement in student sustainability awareness after ESD implementation (Verachtert & Stiers, 2022). The Sustainability and Chemistry in Students Laboratories (SLs) Project (Garner et al., 2015) promotes hands-on chemistry learning related to sustainability. Teachers involved in SLs enhance their knowledge of sustainability issues and integrate Green Chemistry into their teaching. The Virtual School Garden Exchange (VSGE) (Lochner, 2021) allows students to exchange experiences on school gardens and sustainability topics globally, fostering key sustainability competencies through digital communication.

The Young Persons' Plan for the Planet (YPPP) (Ian et al., 2019) aims to increase students' awareness, motivation, and engagement in addressing climate change and promoting renewable energy. Research indicates that students are transitioning from merely being aware of sustainability issues to taking proactive steps to achieve the Sustainable Development Goals (SDGs). China's Green School Program (GSP) (Yuan et al., 2024) integrates government policies with school-led sustainability initiatives, with a focus on water conservation and resource management. Schools are encouraged to lead in promoting environmental awareness. The Climate Change Initiative (Schauss & Sprenger, 2019) engages high school students in research projects on climate change. Students create climate maps, analyze the effects of greenhouse gases, and evaluate the impacts of sustainability on both local and global levels, promoting cognitive, socio-emotional, and behavioral learning.

Together, these initiatives illustrate the diverse and complementary strategies for implementing ESD, from formal curriculum integration and teacher training to student-led experiential learning. By addressing various aspects of sustainability education, these programs help cultivate a generation with the necessary knowledge, skills, and motivation to engage in sustainable practices.

### **Shortcomings of ESD Implementation in K-12 Schools:**

Several of the implementations mentioned above have limitations that need to be addressed when implementing ESD. These include the lack of teaching materials, training opportunities, and practical knowledge on ESD implementation, particularly within classroom-based teaching contexts (Waltner et al., 2020). Therefore, teachers require more tangible support in the teaching domain, increased collaboration with extracurricular learning facilities, and better dissemination of information about ESD.

A closer examination reveals that these limitations are rooted in systemic issues related to teacher preparedness. At the pre-service level, many teacher education programs lack structured and consistent integration of sustainability content, resulting in graduates who are unfamiliar with core ESD concepts and pedagogical approaches. In-service professional development is often sporadic, overly theoretical, and disconnected from teachers' classroom realities, limiting its impact on daily teaching practices. Additionally, structural factors such as limited instructional time, overloaded curricula, and weak institutional support contribute

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to the persistent gap between ESD policy and classroom implementation. These conditions are further compounded by fragmented collaboration between educational institutions and sustainability stakeholders, which hinders the development of coherent and contextually relevant teaching frameworks.

On the other hand, employing trans-disciplinarity in ESD implementation, especially within project-based approaches, also has its challenges. Variations in teachers' perceptions of key ESD concepts and principles can affect transdisciplinary teaching conditions, as well as differences in their roles within the project. Differences in teachers' fundamental pedagogical approaches, such as student-centered or teacher-centered approaches, can impact collaboration dynamics and their ability to engage students in the process. Collaboration is often seen more as a coordination effort rather than a joint creation of new forms, with students often viewed as passive recipients of instruction rather than active partners in collaborative projects (Nordén, 2018). Additionally, striking a balance between student autonomy and guidance in project-based learning is a challenge. While students value the freedom to explore, they often need supervision, especially when conducting research online. Furthermore, project-based learning in ESD tends to focus on localized issues, such as river pollution, but often lacks strong connections to formal school subjects, thereby limiting its curricular integration (Jeziorski et al., 2022).

Beyond challenges related to trans-disciplinarity, another significant barrier lies in integrating transformative perspectives, which necessitate a more holistic and systemic approach to ESD. Regarding this perspective, studies have found that comprehensive implementation in schools remains challenging due to the tendency toward a single-dimensional focus in school practices (Mogren & Gericke, 2017). Other integrative efforts, such as embedding ESD into STEM education, also encounter implementation constraints in formal education settings. These include the disciplinary segmentation of secondary education, which complicates interdisciplinary collaboration, and teachers' limited familiarity with both ESD concepts and specific STEM content. As noted by Paramita et al., (2019), the integration of Circular Economy (CE) into STEM education is similarly hampered by limited teacher knowledge and the complexity of interdisciplinary planning. The absence of clear instructional guidelines further complicates the incorporation of engineering components into STEM-ESD frameworks. Additionally, disconnection between schools and external actors, such as the community or government agencies, limits the potential to integrate community-based knowledge into classroom practices (Bouillion & Gomez, 2001).

Despite its merits, action research, as a method for implementing ESD, is often employed in both classroom and school-wide innovation efforts, and it has inherent limitations. It can be time-consuming for teachers working full-time and requires strong personal commitment, family support, and sustained motivation. Without a genuine belief in the value of the change process, action research initiatives may falter. Furthermore, Husamah et al., (2022) emphasize that cultivating students' action competence through action research requires a consistent process that can be difficult to maintain under heavy teacher workloads. To overcome this, support from school leadership, a collaborative atmosphere among colleagues, and access to academic mentoring are necessary (Linkwitz & Eilks, 2022).

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The implementation of ESD as a school-wide project also encounters practical constraints. A study by Müller et al. (2022) involving school principals in China, Germany, and the United States identified multiple institutional and contextual barriers. These include lack of time and resources, insufficient support, and accountability pressures. In the US context, for instance, the prioritization of standardized performance metrics, particularly in reading and mathematics, often leads to ESD being deprioritized—a trend exacerbated by the disruptions of the COVID-19 pandemic. In China, some school principals pointed to the need for continuous support to help experienced teachers adapt to new approaches. German school leaders cited challenges in recruiting qualified staff with ESD competencies, emphasizing the time and administrative burden associated with this task. Across all three contexts, external pressures from communities, parents, or educational authorities were also seen as barriers to successful ESD implementation.

Other ESD projects, particularly those involving global partnerships, such as the Virtual School Garden Exchange (VSGE), also present unique challenges. These include reinforcing stereotypes, unequal resource access among partner schools, superficial portrayals of cultural contexts, and limited time for meaningful dialogue. Additional risks include students' lack of prior knowledge, which can hinder learning, and the possibility of inappropriate behavior that might offend peers (Lochner, 2021). While these issues are drawn from field-based evaluations and critical reflections in the literature, they reflect real-world challenges in project-based global ESD initiatives. In contrast, the Youth Program for Participatory Planning (YPPP) has been reported to be effective in raising awareness, motivation, and action orientation toward sustainable development (Ian et al., 2019). However, this initiative also has limitations noted in the literature, particularly its partial coverage of the broader dimensions of sustainability.

Following the limitations above, several recommendations can be made to enhance the effectiveness of implementing Education for Sustainable Development (ESD). First, it is crucial to provide comprehensive training and mentoring for educators to address challenges related to ESD implementation (Abidin et al., 2023a; Carrasco et al., 2022). This training should focus on developing skills in ESD principles and practices, as well as providing support for teachers to help them effectively integrate ESD into their teaching (Beltran et al., 2013).

The second suggestion involves enhancing the quality of ESD education in the classroom. This can be done through transdisciplinary learning approaches or by implementing projects related to ESD. Nurturing interdisciplinary connections across various subjects holds the potential to augment a comprehensive grasp of sustainability matters. For instance, integrating elements of environmental, economic, and social sustainability into subjects such as science, social studies, mathematics, and language arts can help students develop a thorough understanding of sustainability challenges (Suárez et al., 2023). Creating an authentic and engaging learning atmosphere can also mitigate disparities in resource allocation, offer ample time for the exchange of ideas, and equip learners with the skills to navigate contradictions and engage respectfully with their peers (Lochner 2021). Furthermore, the inclusion of practical, hands-on learning experiences, such as field trips and community projects, fosters active participation and critical thinking regarding sustainability

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matters, enabling students to apply sustainability principles in real-world scenarios (Suárez et al., 2023).

Lastly, the active participation of school leaders and the community holds paramount importance for the effective implementation of ESD, given their pivotal role in establishing a supportive atmosphere, identifying best practices, and forging innovative collaborations to address ESD comprehensively within their educational institutions (Abidin et al., 2023b; Müller et al., 2021). Hence, it is imperative to provide leadership training and support that empowers school principals to guide their schools toward sustainability and seamlessly incorporate ESD into the school's values and operations (Müller et al., 2019). Programs preparing school principals for their roles, such as master's programs or state-offered courses, should integrate ESD topics, specifically addressing management and leadership aspects, including formulating a vision and mission, managing change, and human resource management tailored for ESD (Müller et al., 2022). Conversely, establishing collaborations with the local community, NGOs, and diverse stakeholders can offer students opportunities to actively contribute to and make a positive impact on the local environment, thereby fostering a heightened sense of ownership and responsibility for sustainable development (Suárez et al., 2023).

Among the various methods reviewed, classroom-based approaches appeared most frequently in the literature due to their practicality and alignment with existing school structures. Integrating ESD topics into regular lessons is more feasible for teachers, as it requires fewer resources and can be adapted to national curricula without major changes. This approach also offers pedagogical flexibility, allowing educators to use methods such as transdisciplinary learning or outdoor activities within familiar classroom settings. Moreover, classroom-based strategies are more commonly documented in research, as they are easier to observe and evaluate compared to large-scale or extracurricular programs.

While commonly reported, Project-Based and Leadership-focused approaches appeared less frequently in the reviewed studies. The limited number of studies on project-based or experiential approaches may be due to constraints such as lack of resources, time, and rigid curricula that reduce flexibility in K–12 schools. These approaches are often implemented as supplementary activities rather than core strategies, making them less likely to be explicitly documented. Similarly, school infrastructure and leadership are seldom the primary focus of research, as ESD studies tend to concentrate more on classroom practices than on managerial or structural aspects of schools. However, research has emphasized the critical role of institutional support, including visionary leadership, whole-school approaches, and policy integration, in ensuring the long-term and meaningful implementation of ESD (Beltrán et al., 2013; Kang, 2019). Therefore, future efforts should aim to strengthen the institutional dimension of ESD, alongside pedagogical innovation, to support a more comprehensive and sustainable integration across school systems.

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## Conclusion

This systematic review analyzed 30 Scopus-indexed articles to examine the implementation of Education for Sustainable Development (ESD) in K–12 schools. The findings reveal that ESD is applied through diverse approaches, with classroom-based methods being the most common due to their alignment with existing curricula. Other techniques, such as project-based learning, textbook integration, and school-wide programs, also contribute to fostering sustainability awareness and competencies among students. However, project-based and leadership-driven initiatives remain less explored, suggesting an imbalance in research focus.

The review highlights several practical implications. Teacher training and pedagogical support are critical to overcoming barriers in implementing ESD, especially for interdisciplinary and transdisciplinary approaches. Additionally, strong leadership and collaboration with local communities are crucial for embedding sustainability in school culture and operations. Ensuring that sustainability themes are reflected in curricula, textbooks, and institutional policies can help establish a more consistent and systemic adoption of ESD across educational settings.

Future research should broaden its scope beyond Scopus to include additional databases and examine ESD implementation at various educational levels. Further studies are also needed to assess the long-term effects of ESD on students' behavior, investigate the use of digital tools, and examine institutional factors such as leadership and policy development. Addressing these gaps will support the development of more effective and scalable models for sustainability education in schools.

## AI-assisted technology statement

While preparing this work, the authors used chatgpt to assist in drafting and refining the text. After utilizing this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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