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Integrating ESD into secondary school curricula: strategies and implementation models

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ABSTRACT

Education for Sustainable Development (ESD) is crucial for fostering students' capacity to address sustainability challenges. Despite its growing application, comprehensive insights into pedagogical strategies are limited. This study conducted a systematic literature review (SLR) in accordance with PRISMA 2020 guidelines, analyzing 29 empirical articles indexed in Scopus, Web of Science, and ERIC. Thematic analysis revealed four key findings: 1) A holistic sustainability competency framework serves as the dominant theoretical foundation; 2) Key pedagogical strategies include project-based learning, STEM-ESD, and inquiry-based learning; 3) Subject-based approaches dominate implementation models, although interdisciplinary and whole-school approaches are gaining ground; and 4) Teacher professional development is a key enabler, while competency gaps and a crowded curriculum are key barriers. Research confirms the positive impact of ESD on sustainability knowledge, attitudes, and critical thinking. These findings suggest that effective ESD integration requires aligning pedagogical innovation with institutional support, ongoing teacher development, and a coherent school culture.

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ABSTRAK

Pendidikan untuk Pembangunan Berkelanjutan (ESD) sangat penting untuk menumbuhkan kemampuan siswa dalam mengatasi tantangan keberlanjutan. Meskipun penerapannya terus berkembang, wawasan komprehensif mengenai strategi pedagogis masih terbatas. Studi ini melakukan tinjauan literatur sistematis (SLR) mengikuti pedoman PRISMA 2020, dengan menganalisis 29 artikel empiris dari Scopus, Web of Science, dan ERIC. Analisis tematik mengungkap empat temuan utama: 1) Kerangka kompetensi keberlanjutan yang holistik berfungsi sebagai landasan teoretis yang dominan; 2) Strategi pedagogis utama meliputi pembelajaran berbasis proyek, STEM-ESD, dan pembelajaran berbasis inkuiri; 3) Model implementasi didominasi oleh pendekatan berbasis mata pelajaran, meskipun pendekatan interdisipliner dan pendekatan seluruh sekolah mulai berkembang; dan 4) Pengembangan profesional guru merupakan faktor pendukung utama, sementara kesenjangan kompetensi dan kurikulum yang padat menjadi hambatan utama. Penelitian mengonfirmasi dampak positif ESD terhadap pengetahuan keberlanjutan, sikap, dan berpikir kritis. Temuan ini menyarankan bahwa integrasi ESD yang efektif memerlukan penyelarasan antara inovasi pedagogis dengan dukungan institusional, pengembangan guru yang berkelanjutan, dan budaya sekolah yang koheren.

Kata Kunci: *ESD; integrasi kurikulum; pendidikan untuk pembangunan berkelanjutan; sekolah menengah; strategi pedagogis*

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INTRODUCTION

Education for Sustainable Development (ESD) has become a global focus in efforts to achieve the United Nations Sustainable Development Goals (SDGs). UNESCO explicitly positions ESD as a key enabler for achieving all SDGs, with Goal 4.7 specifically emphasizing the importance of quality education that enables learners to contribute to sustainable development (Dalampira & Nastis, 2020; Holst et al., 2023).

At the secondary school level, ESD becomes crucial because students at this stage can think abstractly, analyze complex systems, make informed moral decisions, and engage in more meaningful social action. ESD is not simply an integration of environmental content, but rather the development of comprehensive sustainability competencies encompassing knowledge, values, critical thinking skills, systems thinking, and the ability to act (Özdemir et al., 2021; Pratiwi et al., 2025; Vilmala et al., 2022).

Various countries have developed policies and programs to integrate ESD into secondary school curricula, ranging from adding environmental content in specific subjects to cross-disciplinary approaches to whole-school models that address school culture and governance (Habibaturrohmah et al., 2023; Wals & Mathie, 2022). However, implementation of ESD in the field shows high variability across pedagogical strategies and curriculum integration models. Furthermore, there has been no comprehensive systematic synthesis that identifies general patterns in ESD implementation strategies and models at the secondary school level globally.

This Systematic Literature Review (SLR) is designed to answer the following four research questions:

Q1: What theoretical frameworks and sustainability competency models are used in studies on the integration of PPB in secondary schools?

Q2: What pedagogical strategies are most frequently used to integrate PPB into learning in secondary schools?

Q3: What implementation models (subject-based, cross-curricular, whole-school) are emerging across secondary school contexts?

Q4: What are the main findings regarding the impact, supporting factors, and barriers to implementing PPB in secondary schools?

Literature Review

Education for Sustainable Development (ESD)

UNESCO, on its website (www.unesco.org/en/sustainable-development/education/), states that ESD is an approach that positions education as a key to advancing progress across all global development goals. It teaches individuals to make informed decisions and take action, both individually and collectively, to change society and protect the planet. Education is the most strategic way to cultivate, implement, and promote values of sustainable development and to increase human capacity to overcome environmental and development challenges

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(Vilmala et al., 2022). The concept of ESD must be applied at multiple levels within the school. ESD implemented in schools is considered effective in raising awareness among the current generation, thereby fostering respect for the environment among future generations (Ismail et al., 2024).

ESD advocates for learning is (Riess et al., 2022):

1. Cognitive: improving how we think and understand information.
   For beginner learners, they lack in-depth knowledge and competence (expertise) in a specific subject or a content domain can try methods with a higher degree of guidance by the teacher (e.g., direct instruction and a problem-based teaching and learning model), which might be the first choice for promoting the development of knowledge and problem-solving skills. As expertise increases, fostering greater self-direction through appropriate methods (e.g., project work, discovery learning) becomes increasingly important, particularly in light of motivational psychology. However, independently of the methods used, educators should be aware of the expertise-reversal effect. Support measures that are beneficial for learners with low levels of prior knowledge (e.g., scaffolding prompts and worked examples) lose their effectiveness and sometimes even have detrimental effects for learners with higher levels of prior knowledge.
2. Socio-emotional: building social skills, empathy, and emotional intelligence.
   Potentially suitable methods to facilitate socio-emotional learning include role-playing, simulation games, learning from models (observation and imitation learning), value clarification, projects, internships in sustainability-relevant contexts, and the formation of student parliaments in which learners participate in decisions on sustainability-related matters.
3. Behavioral: encouraging positive actions and behaviors.
   For example, teachers should raise awareness (and problematize) their students' action-guiding ideas and assumptions (subjective theories) and foster their self-efficacy so that they believe their actions have an effect. Teachers can achieve this change, for example, by supporting the formation of concrete action plans, stimulating self-commitment, visualizing outcomes, and using reminders.

Integration of ESD in secondary schools

The paradigm shift in integrating ESD in secondary schools, moving from the mere insertion of environmental content to the development of holistic sustainability competencies, is increasingly supported by recent research. UNESCO emphasizes the importance of a holistic, transformative approach that encompasses content, learning outcomes, pedagogy, and the learning environment, necessitating a whole-institution approach. Transformative learning processes, critical thinking, and inter- and transdisciplinary approaches are fundamental to developing sustainability competencies (Brundiers et al., 2021). Although the subject-based model remains dominant, there is a clear increase in the adoption of interdisciplinary and whole-school approaches, indicating a recognition of the importance of multi-level integration for consistent learning. This also aligns with the need to formalize a clear sustainability competency map, such as the European Sustainability Competence Framework

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(GreenComp), which encompasses cognitive, affective, and behavioral dimensions (Bianchi et al., 2022).

METHODS

This section discusses the methodology for identifying global publications on the implementation of ESD in secondary schools, with a particular focus on pedagogical strategies and implementation models. The SLR method was chosen because it enables a comprehensive, organized examination of the existing literature, thereby identifying trends, gaps, and areas of agreement in this field (Mengist et al., 2020).

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 checklist was used to conduct the SLR and answer the established research questions. PRISMA 2020 is a revised and published international standard for conducting high-quality SLRs with full transparency (Page et al., 2021). Consequently, the PRISMA 2020 checklist served as a comprehensive guide for this study, ensuring structured and systematic reporting throughout the review process. This SLR involves three main phases: identification, screening, and eligibility assessment. Each phase is designed to ensure the inclusion of relevant studies and the exclusion of studies that do not meet the criteria.

This review draws on research publications indexed in Scopus, Web of Science, and ERIC databases from 2015 to 2025 as its primary data source. 2015 was chosen as the starting point because it was the first time the SDGs were officially endorsed and marked a significant increase in research on integrating ESD in secondary schools through innovative pedagogical approaches. On September 21, 2025, a literature search was conducted using Scopus, Web of Science, and ERIC databases with a comprehensive search string that included: "Education for Sustainable Development" OR "ESD" OR "Sustainable Education" OR "Sustainable Development" OR "SDGs in Education" OR "Sustainability Education" for ESD dimensions; "secondary school" OR "middle school" OR " junior high school" for educational levels; "pedagogical strategies" OR "teaching approaches" OR "project-based learning" OR "inquiry-based learning" OR "STEM" OR "co-creation" for pedagogical strategies; and "curriculum integration" OR "implementation model" OR "whole-school" for implementation model. This keyword combination covers the full spectrum of literature on integrating ESD in secondary schools. This search yielded 280 articles published between 2015 and 2025.

The screening process aimed to eliminate duplicate, irrelevant, or non-compliant articles. Initially, 157 duplicate publications were removed using reference management software (EndNote/Mendeley), resulting in 123 unique articles for further review. Of these 123 articles, the authors screened titles and abstracts using established inclusion and exclusion criteria. At this stage, 60 articles were excluded for apparent non-relevance to the SLR topic, resulting in 63 articles that were then assessed for eligibility through full-text review. Of the 63 articles uploaded for full-text assessment, 34 articles were excluded because they 1) Did not focus on secondary schools (26 articles); 2) Focused on environmental education without an explicit ESD/SDGs framework (5 articles); or 3) Were review/conceptual articles without empirical data (3 articles). In total, 29 studies were eligible for analysis in this systematic review. Twenty-nine articles were identified as meeting all inclusion criteria and were

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included in the final analysis. **Figure 1** illustrates the inclusion and exclusion flow of articles according to the PRISMA 2022 reporting standards.

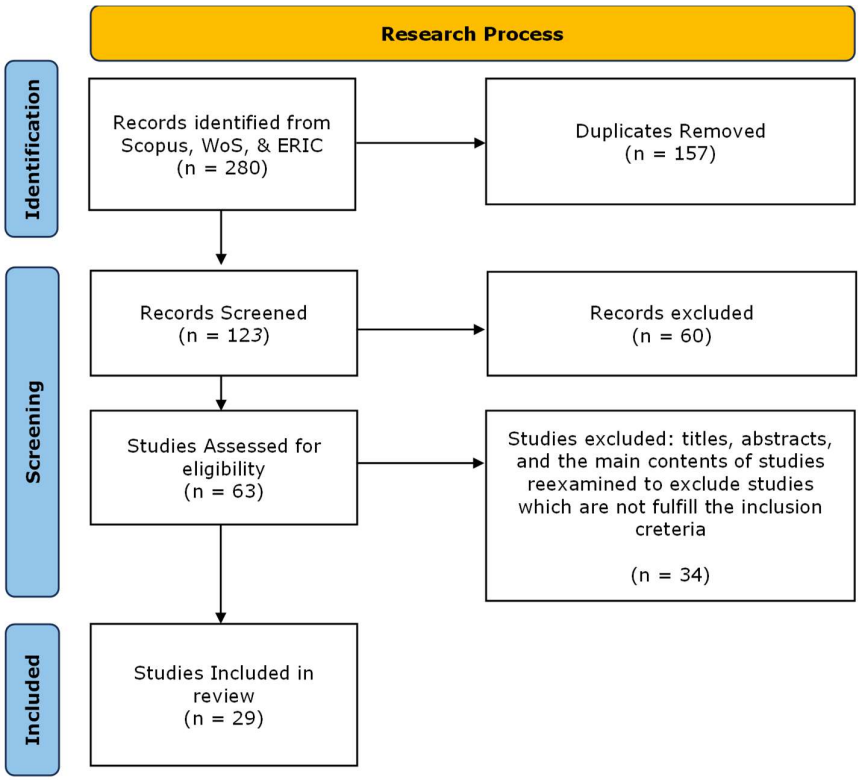

Figure 1. PRISMA flowchart
Source: Page et al. *(2021)*

RESULTS AND DISCUSSION

General Characteristics of the Reviewed Studies

From the 29 articles analyzed in this systematic review, a comprehensive overview of the research profile on ESD integration in secondary schools was obtained. **Appendix 1** presents detailed information for each study, including the researcher's identity, the study's geographic location, the journal in which it was published, the thematic focus, the methodological approach, and the characteristics of the study sample.

The geographic distribution of studies shows a significant concentration in Europe (52% of the 29 studies), with countries such as Germany, Sweden, Spain, and Norway leading in research on ESD implementation. Asia accounts for 28% of studies (primarily Indonesia, Vietnam, China, and Bangladesh), Africa for 10% (Tanzania, South Africa), and the Americas for 7% (Greece, Turkey, and the United States). This distribution pattern indicates uneven research capacity and underscores the need to expand ESD research in underrepresented regions, particularly Latin America, the Pacific, and sub-Saharan Africa.

In terms of methodology, the majority of studies employed a qualitative approach (41%; 12 studies) or mixed methods (38%; 11 studies), whereas quantitative studies accounted for 21% (6 studies). The dominance of qualitative and mixed-methods approaches reflects the complexity of ESD implementation, which quantitative measures alone cannot fully capture.

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These methods enable researchers to explore implementation processes, stakeholder perceptions (teachers, students, administrators), mechanisms of change, and the local context influencing program effectiveness.

Research samples vary widely in size and composition. Some studies use single-case designs with a few dozen participants (e.g., 15 teachers in Malaysia, 30 students in Sweden), while others involve large-scale studies with thousands of participants (1,622 students in Germany) and 635 teachers in Vietnam. This variability reflects the diversity of educational contexts, from local schools with specific cultures to cross-national studies aimed at identifying global patterns. The profiles of these 29 studies provide a comprehensive audit trail, allowing readers to trace the source of each claim or finding that appears in subsequent thematic analyses. **Appendix 1** serves as a quick reference for identifying which studies are most relevant to the reader's specific context, thematic focus, or methodology.

Temporal Trends and Geographic Distribution

To provide a more in-depth understanding of the ESD research landscape in secondary schools, four descriptive visualizations are presented below.

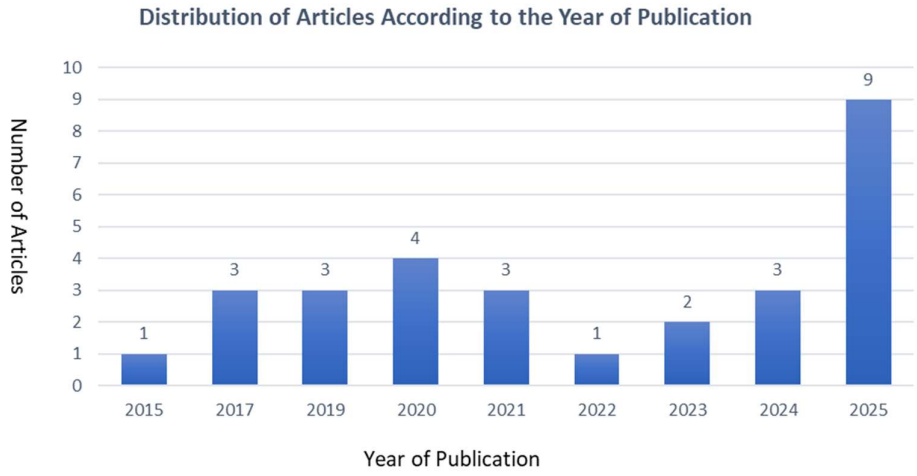

Figure 2. Distribution of Articles According to the Year of Publication
Source: Researcher, 2025

Figure 2 displays the trend of publications on ESD integration in secondary schools from 2015 to 2025. The graph shows that publications increase, with the peak in research activity occurring in the final years (2023-2025). This increase can be attributed to several factors: 1) The ratification of the SDGs in 2015 which explicitly places quality education (SDG 4) as a global priority; 2) UNESCO's strengthening positioning of ESD as a key enabler for the achievement of all SDGs; and 3) growing global awareness of the urgency of climate change and the sustainability crisis which is driving education for change.

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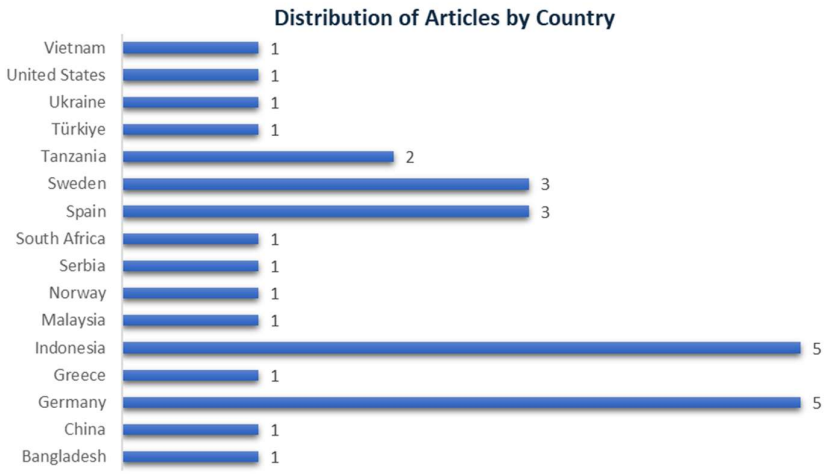

Figure 3. Distribution of Articles by Country
Source: Researcher, 2025

Figure 3 illustrates the geographic distribution of studies by country of study. This visualization clearly shows the concentration of research in Europe, particularly in Germany, Sweden, Spain, the UK, and Norway. This concentration reflects significant investment in sustainability education research in Europe, a strong policy commitment to ESD, and a mature research infrastructure. However, this distribution also identifies research gaps that need to be filled in other regions, particularly Latin America (where only Greece/Europe is represented), sub-Saharan Africa (where only Tanzania and South Africa are represented), and the Pacific (where there is almost no representation). This pattern suggests that generalizing findings to non-European contexts should be undertaken with caution and that local research in underrepresented regions should be prioritized.

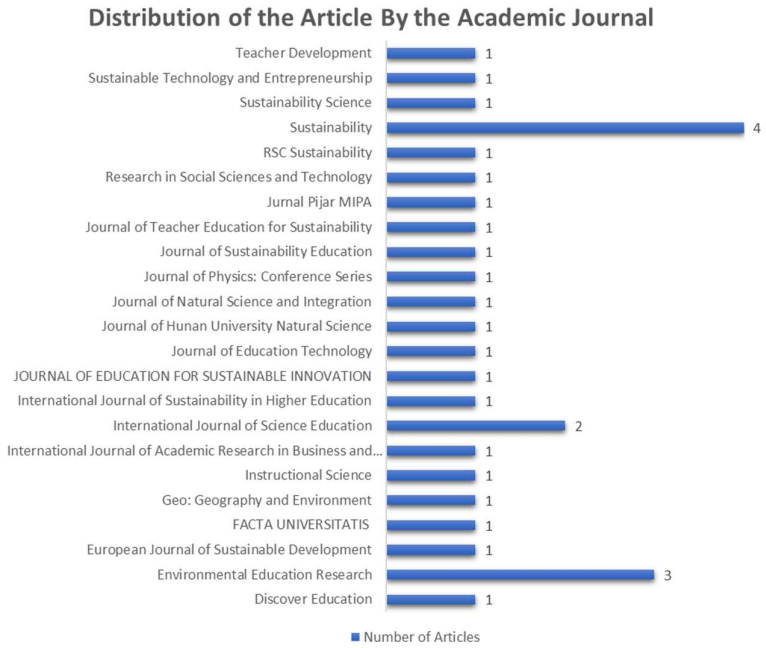

Figure 4. Distribution of the Articles by the Academic Journal
Source: Researcher, 2025

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Figure 4 shows the distribution of articles based on academic journals publishing ESD research. Key journals such as Sustainability, Environmental Education Research, International Journal of Science Education, Journal of Teacher Education for Sustainability, and several local journals show the highest publication frequency. Identifying these publication venues is important for several reasons: 1) It helps the research community identify appropriate target journals for publication of their work; 2) it provides an overview of the academic ecosystem in the ESD field; and 3) it allows tracking of topic and methodological trends in the indexed literature in specific journals. The dominance of certain journals also indicates a robust editorial and peer-review network that supports the publication of high-quality ESD research.

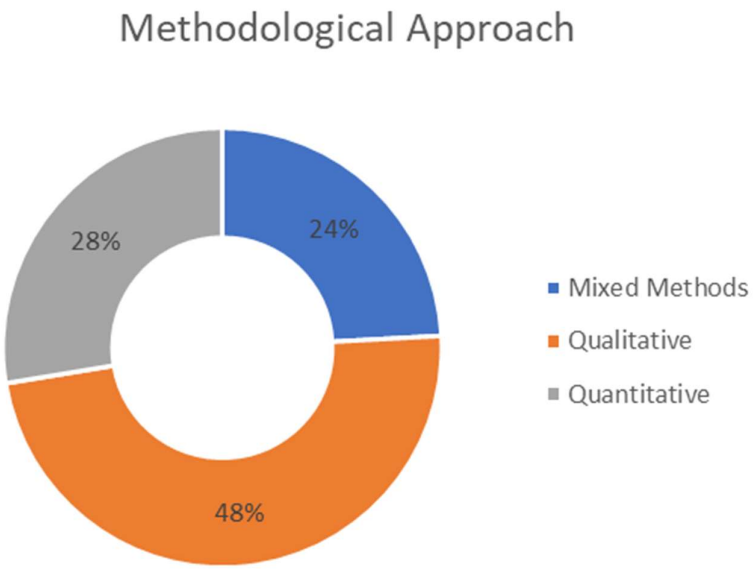

Figure 1 Methodological Approach
Source: Researcher, 2025

Figure 5 presents the distribution of articles based on the methodological approach used in the 29 reviewed studies. The graph shows that qualitative studies (48%, 14 studies) predominate, whereas quantitative studies (28%, 8 studies) and mixed-methods studies (24%, 7 studies) account for smaller shares. This pattern is significant and reflects the inherent characteristics of the ESD phenomenon in secondary schools. First, ESD implementation is a complex process involving pedagogical change, organizational culture, and stakeholder mindset transformation—a difficult aspect to measure with simple quantitative instruments. Second, local contexts, teacher and student perceptions, institutional barriers, and program adaptation mechanisms are highly contextual and require an in-depth understanding, better achieved through qualitative methods. Third, a mixed-methods approach allows researchers to combine the strengths of both approaches: qualitative exploration to understand processes and meanings, and quantification to provide evidence of impact that can be compiled and compared across contexts.

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Synthesis of Findings From 29 Studies

An in-depth analysis of 29 articles yielded comprehensive thematic findings on theoretical frameworks, pedagogical strategies, implementation models, and the impacts, supporting factors, and barriers to ESD implementation in secondary schools. **Appendix 2** provides the basis for data extraction in this systematic review. It displays the exact data from each article, including its title, specific research question, and key findings. This appendix provides full transparency into how the 29 individual studies contributed to the broader thematic synthesis. Readers can readily trace the origins of any claims or patterns that emerge in the subsequent thematic analysis, thereby enhancing the auditability and credibility of the findings.

The diversity seen in **Appendix 2** reflects the complexity of the ESD field. Some studies focus on specific competencies (e.g., critical thinking skills in Bangladesh; sustainability competencies in Germany), while others examine specific pedagogical strategies (project-based learning in Greece; STEM-ESD in Vietnam; co-creation in Sweden). Some studies examine stakeholder perceptions (pre-service teachers in Spain, practicing teachers in Tanzania, technology teachers in South Africa) and whole-school program implementation (Adiwiyata in Indonesia, school climate assemblies in Spain, sustainability programs in Ukraine). This diversity indicates that the field of ESD is rich and multifaceted, offering substantial opportunities for further research and synergies across perspectives.

ESD Theoretical Framework and Competencies

Analysis of the theoretical framework used reveals several dominant patterns:

1. Holistic Sustainability Competency Model. Another study developed and validated a 52-item instrument to measure secondary students' sustainability competencies across the cognitive (knowledge), affective (values and attitudes), and behavioral (sustainable actions) domains, with significant gender differences reported (Waltner et al., 2019). A comprehensive scoping review of 35 peer-reviewed publications identified a range of competency frameworks, from transversal models to specific cognitive, affective, or behavioral frameworks, with the majority originating from European contexts (Sposab & Rieckmann, 2024).
2. ESD as a Curriculum Innovation. In Indonesia, ESD is positioned as an integral educational innovation in the formation of environmentally conscious character, with an emphasis on the dynamic relationship between knowledge, attitudes, and sustainable behavior (Ali et al., 2022; Mulyadi et al., 2023; Prabawani et al., 2020; Safira et al., 2025).
3. Systems Thinking and Socio-Scientific Issues (SSI). Several Scandinavian studies have used the SSI framework and the critical scientific habits of mind to analyze how students and teachers understand and debate complex and controversial sustainability issues (Bašić & Davidsson, 2025; Jegstad & Sinnes, 2015; Ojala et al., 2025).

In general, the theoretical frameworks across the 29 studies are consistent with UNESCO's recommendation that sustainability competencies should include systems thinking, critical thinking, collaboration, and the ability to act for sustainability.

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Pedagogical Strategies for ESD Integration

Six main groups of pedagogical strategies were identified:

1. Project-Based Learning (52%, 15 studies). Project-based learning places sustainability issues in an authentic and urgent context. Student-led sustainability projects enhance students' knowledge, critical thinking, sense of agency, and well-being through authentic integration of learning and socio-environmental action (Vare, 2021). Project-based STEM activities (designing sustainable products) significantly improved students' attitudes toward sustainable development across all dimensions (social, environmental, and economic) (Diepolder et al., 2025).
2. STEM-ESD Integration (26%, 8 studies). PRISMA-based SLR identified five key strategies for ESD integration into STEM: 1) Integrating SDGs concepts; 2) Emphasizing hands-on and experimental activities; 3) Designing real-world problems related to sustainability challenges; 4) Building partnerships with local communities and industries; and 5) Providing ongoing training and resources for teachers (Habibaturrohmah et al., 2023). Teachers in Vietnam view STEM as a powerful approach to addressing development challenges through the creation of authentic problems and the development of innovative solutions (Nguyen et al., 2020).
3. Inquiry-Based Learning (21%, 6 studies). A chemistry-based inquiry on "material degradation in the context of sustainability" trained students to design medium- to long-term investigations and relate findings to green chemistry principles and global environmental impacts (López-Fernández et al., 2025). Their project integrated science with sustainability awareness through hands-on exploration.
4. Socio-Scientific Issues and Controversial Issues. In Sweden, four traditions of teaching controversial sustainability issues were identified: fact-based science-oriented, fact-based against values, pluralistic, and normative (Ojala et al., 2025). The pluralistic and normative traditions were more strongly associated with learning about multiple perspectives and with sustainable action. Students who learned about complex sustainability issues developed three competencies: handling uncertainty, appreciating multiple perspectives, and developing action competencies (Kater-Wettstädt, 2018).
5. Co-Creation with Professionals and Communities. Showed that collaboration between students, teachers, and science professionals (urban planners, hydrologists, biologists) in designing solutions to local sustainability dilemmas enhances scientific reasoning, engagement, and critical thinking, while providing authentic experiences of the application of science in solving socio-environmental problems (Bašić & Davidsson, 2025).
6. Digital Technology, Blended Learning, and XR/VR. Blended learning ESD in junior high school science resulted in significant increases in students' environmental conservation knowledge and attitudes (Ali et al., 2022). An XR application on biodiversity in German secondary classrooms was associated with increased knowledge of biodiversity. However, the impact on environmental interest was not as strong as expected, indicating the need for a combination with deeper reflective pedagogy (Mulders et al., 2025).

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ESD Implementation Model

Three models of PPB implementation stand out in the literature:

1. Subject-Based Infusion (62%, 18 studies). This model integrates ESD into specific subjects. Mwendwa (2017) reported that in Tanzania, ESD is primarily delivered through geography and biology courses that address conservation, climate, and local environmental issues; however, its application outside the classroom remains limited due to weak teacher competency and institutional support. A "Chemistry Teaching for the Future" model with five categories (Chemistry Content, Chemistry in Context, Chemistry's Distinctiveness, ESD Competences, Lived ESD) that allows chemistry teachers to systematically integrate sustainability without increasing the curriculum burden (Jegstad & Sinnes, 2015). In South Africa, technology teachers understood ESD concepts and curricular opportunities (projects, local knowledge, collaboration), but classroom practice remained predominantly demonstration-based rather than active pedagogy (Blose, 2025).
2. Cross-Subject/Interdisciplinary Approach (45%, 13 studies). A comparative study in Sweden found that science teachers tended to focus on ecological facts (ESD Type I), social studies teachers on social issues and critical thinking (ESD Type II), and language teachers on personal development and communication (ESD Type III) (Sund & Gericke, 2020). Collaboration across these three areas has great potential to achieve the SDGs holistically. The integration of the SDGs into China's national curriculum has increased in physical education, health, and biology, but there remain gaps in the arts and in certain SDGs (5 and 12) (Yuan & Yu, 2024). In Indonesia, the integration of the SDGs into the science learning pathway is reflected in learning outcomes related to the interaction of living things, pollution prevention, biotechnology, and disaster mitigation in the Kurikulum Merdeka (Mulyadi et al., 2023).
3. Whole-School Integration (28%, 8 studies). The Adiwiyata program in Indonesia integrates school environmental management (e.g., parks, waste banks, composting), energy- and water-saving practices, parent and community involvement, and disaster simulations as a form of ESD within school culture (Prabawani et al., 2020; Safira et al., 2025). Implementation analysis indicates that approximately 95% of ESD environmental indicators have been implemented through the strong integration of curriculum and school culture. School climate assemblies in Spain position students as co-creators of school climate policies, leading to high student satisfaction and a range of progressive policy recommendations, while developing students' sustainability competencies and agency as agents of change (Cebrián et al., 2024). Studies in Ukraine, Serbia, Montenegro, and Croatia show that consistently applied ESD philosophy and practices across multiple school dimensions result in more stable positive attitudes and sustainable behaviors (Vukić et al., 2021; Vysotska et al., 2021).

Impact, Supporting Factors, and Barriers

A systematic review of 29 studies found that ESD interventions consistently had positive effects, including increased sustainability knowledge in 79% of studies, increased sustainability attitudes in 69% of studies, and improved critical and systems thinking skills in 55% of studies. Strengthening student agency and action competencies was noted in 48%

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of studies, and an increase in sustainable entrepreneurial orientation was documented. Key supporting factors for successful ESD integration include ongoing teacher professional development through structured training, aligned supportive policies at the school and national levels, effective school leadership, and strong community partnerships.

However, several significant barriers were also identified, including limited teacher competence, perceived heavy curricular workloads, inadequate institutional support, limited resources and infrastructure, and knowledge-behavior gaps that warrant attention. Research also highlights the need for specialized pedagogies to address controversial sustainability issues such as climate change, biodiversity, and social justice by incorporating multiple perspectives and concrete actions. Furthermore, integrating green skills across subjects and leveraging digital technologies, such as blended learning and XR/VR, has been shown to increase student engagement. However, they require thoughtful and reflective pedagogical design. In the Indonesian context, the integration of ECD through the Kurikulum Merdeka and the Profil Pelajar Pancasila creates significant opportunities for the structured, sustained development of sustainability competencies in secondary schools.

Discussion

The paradigm shift in the integration of ESD in secondary school, as mentioned in the literature review before, can be supported by the normalization of project-based and inquiry-based learning, where authentic projects rooted in local issues and community action have proven highly effective in developing sustainability competencies (AlAli et al., 2023; Olsson et al., 2022). The integration of innovative pedagogies such as STEM-ESD, Socio-Scientific Issues (SSI), co-creation, and digital technologies requires a structured approach, supported by ongoing teacher professional development (Fakhrudin et al., 2021; Stouthart et al., 2023). A concrete example of the co-creation approach is "school climate assemblies," which involve students in decision-making regarding climate change (Cebrián et al., 2024). The three-layer integration model—classroom layer, cross-subject curriculum layer, and school culture/policy layer—supported by UNESCO's whole-institution approach, provides a comprehensive framework. In the Indonesian context, these findings are highly relevant, where the flexibility of the Kurikulum Merdeka and the Profil Pelajar Pancasila can be leveraged to integrate ESD through projects addressing local problems, as demonstrated by research on STEM-ESD integration in Indonesia (Abdurrahman et al., 2023; AlAli et al., 2023).

General Pattern of PPB Integration in Secondary Schools

A synthesis of 29 studies reveals a paradigm shift in ESD integration, moving from the traditional "environmental content insertion" model to a broader, more holistic approach to developing sustainability competencies. The dominant model remains subject-based (62%), but interdisciplinary (45%) and whole-school (28%) approaches are increasingly prevalent. This pattern indicates that educational institutions are recognizing the importance of multi-level integration to ensure continuous, consistent learning about sustainable development.

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Implications for Curriculum Design and Learning

1. Formalize the Sustainability Competency Map. A clear competency framework (cognitive, affective, and behavioral) needs to be institutionalized across all schools and integrated with subject learning outcomes.
2. Normalization of Projects and Inquiry-Based Learning. Authentic projects that address local issues and connect formal learning to real community action have proven highly effective in developing sustainability competencies.
3. Integrate Innovative Pedagogies in a Structured Way. STEM-ESD, SSI, co-creation, and digital technologies need to be integrated systematically, with ongoing support for teacher professional development.
4. Develop a Three-Layer Model of ESD Integration: 1) Classroom Layer: project-based learning, inquiry-based learning, SSI, co-creation, STEM-ESD, digital technology; 2) Cross-Subject Curriculum Layer: collaborative planning between teachers, mapping the unique contributions of each subject, explicit integration of SDGs; 3) School Culture and Policy Layer: school environmental programs, school climate assemblies, sustainable resource management, community partnerships, energy-water saving policies, disaster simulations.

Indonesian Context: Kurikulum Merdeka and Profil Pelajar Pancasila

The SLR findings are highly relevant to the Indonesian context. The implementation of the Kurikulum Merdeka and the Profil Pelajar Pancasila creates a more flexible framework for integrating PPB. Educational units can design a sustainability-themed Proyek Penguatan Profil Pelajar Pancasila (P5) that connects formal learning with real-world local issues (water, waste, food, and disaster mitigation management). The Adiwiyata program, which has proven effective in Indonesia, can be strengthened with a STEM-ESD approach, project-based learning, and school climate assemblies to maximize the impact of sustainability learning (Safira et al., 2025; Prabawani et al., 2020).

Recommendations for Educational Practice

For educational units, develop a clear vision for ECE, integrate it into curriculum planning, allocate regular time for teacher collaboration, facilitate ongoing professional development, and build local community and industry partnerships. For Teachers, engage in collaborative learning, develop competencies in designing project-based learning based on local issues, integrate sustainability perspectives in their respective subjects, use various pedagogical strategies (inquiry, SSI, co-creation, technology), and conduct continuous assessments of students' sustainability competencies. For policymakers, allocate funds for ESD teacher professional development, revise curriculum standards to ensure ESD integration, support schools in implementing whole-school ESD, and facilitate partnerships between educational units, communities, and environmental stakeholders.

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CONCLUSION

The research indicates that the dominant theoretical framework is holistic sustainability competency, encompassing the cognitive, affective, and behavioral domains, with an emphasis on systems thinking and critical thinking, consistent with UNESCO's vision for ESD. The most effective and frequently implemented pedagogical strategies include project-based learning, STEM-ESD integration, inquiry-based learning, and socio-scientific issues-based approaches, co-creation with professionals, and digital technology—all focused on authentic learning that addresses real-world issues. ESD implementation models are divided into three main levels: subject-based infusion, interdisciplinary approaches, and whole-school integration, demonstrating a trend toward holistic integration. Positive impacts of ESD implementation were observed in significant increases in sustainability knowledge, attitudes, and critical thinking, as well as in students' empowerment as agents of change. However, challenges remain regarding the gap between knowledge and behavior. Critical factors for the success of this integration include ongoing teacher professional development, policy alignment at the institutional and national levels, strong support for school leadership, and effective community partnerships. These findings provide an important foundation for developing sustainability education policies and practices at the secondary school level and contributing to the achievement of the SDGs.

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APPENDIX

Appendix 1. Reviewed Studies on ESD Integration in Secondary Schools

No	Author and year (citation)	Country	Journal	Context	Methodological approaches	Sample
1	Diepolder et al. (2025)	Germany	Sustainable Technology and Entrepreneurship	Sustainable Entrepreneurship Education	Quantitative	169 students
2	Sund & Gericke (2020)	Sweden	Environmental Education Research	cross-curricular teaching	Qualitative	43 teachers
3	Vare (2021)	Greece	Sustainability	Student-led sustainability projects (student agency)	Mixed Methods	100 students, 15 teachers
4	Cebrián et al. (2019)	Spain	International Journal of Sustainability in Higher Education	Pre-service secondary teachers' perceptions	Quantitative	183 teachers
5	Mwendwa (2017)	Tanzania	Journal of Sustainability Education	Integration of Environmental Education (EE)	Qualitative	40 students
6	Jegstad & Sinnes (2015)	Norway	International Journal of Science Education	Chemistry Teaching for the Future	Qualitative	model and theoretical discussion
7	Sposab and Rieckmann (2024)	Germany	Sustainability	Development of Sustainability Competencies	Mixed Methods	35 peer-reviewed publications
8	Kater-Wettstädt (2018)	Germany	Environmental Education Research	Various ESD topics	Qualitative	160 lessons
9	Mulyadi et al. (2023)	Indonesia	Journal of Educational Technology	ESD Competency and Implementation	Mixed Methods	384 teachers
10	Ali et al. (2022)	Indonesia	Journal of Hunan University Natural Science	Infused ESD	Mixed Methods	216 Students
11	Jonas & Ephrem (2025)	Tanzania	Journal of Education for Sustainable Innovation	Geography, Biology, Chemistry, Mathematics, Civics, Physics, Art, History.	Qualitative	24 teachers
12	Vysotska et al. (2021)	Ukraine	European Journal of Sustainable Development	environmental, legal, socio-economic, and moral/ethical components of ESD	Mixed methods	122 School.
13	Vukić, Jovanović, & Todorović (2021)	Serbia	Facta Universitatis	goals and objectives of specific courses/areas	Qualitative	documents and guidelines
14	Nguyen et al. (2020)	Vietnam	Sustainability	STEM education focuses on integrating sustainability concepts and addressing real-world development challenges	Qualitative	635 teachers

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No	Author and year (citation)	Country	Journal	Context	Methodological approaches	Sample
15	Prabawani et al. (2020)	Indonesia	Journal of Teacher Education for Sustainability	Environmental knowledge, attitudes, and behaviors related to ESD	Quantitative	336 students
16	Blose (2025)	South Africa	Research in Social Sciences and Technology	Technology Education curriculum,	Qualitative	8 teachers
17	Kamis et al. (2017)	Malaysia	International Journal of Academic Research in Business and Social Sciences	Green skills	Qualitative	15 teachers
18	Yuan & Yu (2024)	China	Geo: Geography and Environment	Integration of Sustainable Development Goals (SDGs)	Qualitative	Curriculum documents
19	López-Fernández et al. (2025)	Spain	RSC Sustainability	green chemistry	Mix methods	25 Students
20	Moore et al. (2019)	United States	Teacher Development	science, social studies, language arts	Qualitative	15 teachers
21	Mulders et al. (2025)	Germany	Instructional Science	biodiversity, environmental protection, Amazon rainforest,	Quantitative	172 students
22	Ürek et al. (2025)	Turkish	Discover Education	STEM+ activity	Quantitative	20 Students
23	Cebrián et al. (2024)	Spain	Sustainability Science	School climate assemblies	Mixed Methods	43 school members, 586 students
24	Ojala et al. (2025)	Sweden	Environmental Education Research	Environmental and Sustainability Education (ESE)	Quantitative	378 teachers
25	Bašić & Davidsson (2025)	Sweden	International Journal of Science Education	science learning	Qualitative	30 Students
26	Habibaturrohmah et al. (2023)	Indonesia	Journal of Natural Science and Integration	STEM Education	Qualitative	20 Empirical articles
27	Safira et al. (2025)	Indonesia	Journal of Science and Technology	Implementation of ESD values in environmental aspects	Qualitative	21 respondents
28	Uddin et al. (2020)	Bangladesh	Journal of Physics: Conference Series	Critical Thinking Skills	Quantitative	444 students
29	Waltner et al. (2019)	Germany	Sustainability	Sustainability competencies	Quantitative	1622 students

Source: Researcher, 2025

Appendix 2. Summary of findings for the selected SLR studies

No	Title	Aim	Finding
1	Effects of competency-based sustainable entrepreneurship education on secondary school students' sustainable entrepreneurial intention	To evaluate the impact of competency-based Sustainable Entrepreneurship Education (SEE) on secondary school students' Sustainable Entrepreneurial Intentions (SEI) and related attitudes.	SEE significantly increases students' sustainable entrepreneurial intentions, attitudes, subjective norms, and perceived behavioral control, with no gender differences. Role models enhance outcomes but are not essential, supporting SEE's integration into the secondary curriculum.
2	Teaching contributions from secondary school subject areas to education for sustainable development - a comparative study of science, social science and language teachers	To investigate the potential ESD teaching contributions from science, social science, and language teachers by analyzing their content, methods, and purposes	Science teachers provide ecological facts (ESD I), social science teachers focus on social issues and critical thinking (ESD II), and language teachers support personal development and communication (ESD III). These distinct yet complementary roles demonstrate strong potential for collaborative, holistic cross-curricular ESD.

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No	Title	Aim	Finding
3	Exploring the Impacts of Student-Led Sustainability Projects with Secondary School Students and Teachers	To investigate the impacts of student-led sustainability projects on secondary students and teachers within formal education.	Student-led projects provided an authentic ESD context, integrating knowledge, critical thinking, and action on social/environmental issues. This transformative approach fostered student agency and well-being and contributed to the evolution of schooling for sustainable development.
4	Perception of sustainability among Spanish pre-service secondary school teachers' competencies	To assess Spanish pre-service teachers' self-perceived sustainability competencies and the factors influencing them.	Teachers reported medium competence, significantly boosted by prior teaching experience and participation in sustainability projects, emphasizing "learning by doing" ESD.
5	Learning for Sustainable Development: Integrating Environmental Education in the Curriculum of Ordinary Secondary Schools in Tanzania	To assess the integration of Environmental Education (EE) in Tanzanian secondary school curriculum for sustainable education, identifying subjects, perceptions, and challenges.	EE, a core component of ESD, is integrated into the Tanzanian secondary curriculum through Geography and Biology, covering sustainable development topics such as climate and conservation. While students and teachers demonstrate a fair understanding of basic EE, application outside the classroom is limited. Challenges to effective ESD implementation include inadequate teacher knowledge/training, a lack of institutional support, cultural beliefs, and issues with content relevance.
6	Chemistry Teaching for the Future: A model for secondary chemistry education for sustainable development	This paper proposes a model for integrating Education for Sustainable Development (ESD) into secondary chemistry education, enabling teachers to implement it within existing curricula.	The research introduces a five-category elliptic model (Chemical Content Knowledge, Chemistry in Context, Chemistry's Distinctiveness, ESD Competences, and Lived ESD) to integrate ESD into secondary chemistry. This framework helps teachers embed sustainability principles and foster responsible citizenship by focusing on relevant content, contextualization, and the development of key ESD competencies without creating curriculum overload.
7	Development of Sustainability Competencies in Secondary School Education. A Scoping Literature Review	To identify and assess sustainability competency frameworks and pedagogical approaches in global secondary education, outlining current practices and research gaps.	Global research emphasizes holistic sustainability competencies (e.g., critical and systems thinking) in secondary education, fostered by active, interdisciplinary pedagogies. Frameworks range from transversal to specific cognitive/affective/behavioral models. A European research bias exists, calling for more diverse, collaborative approaches.
8	How secondary-school students deal with issues of sustainable development in the classroom	To investigate how secondary school students engage with complex sustainable development issues in classroom settings and the strategies they employ.	Identified three key student competencies in ESD: dealing with uncertainty, perspective, and calls to action. Student strategies vary significantly by pedagogical approach (teacher-centered vs. student-centered), shaping their engagement with knowledge and perspectives.
9	Correlational Study: Teacher Perceptions and The Implementation of Education for Sustainable Development Competency for Junior High School Teachers	Analyze the relationship between teacher ESD competence perceptions and ESD implementation in Junior High Schools (JHS)	Teachers consider ESD competence necessary but perceive its implementation as average, and they want deeper competence. A positive but low correlation exists between perceived competence and implementation
10	Blended Learning in the Implementation of Environment Dimension of ESD Infused into Junior High School Science	The main objective of this study was to examine the effectiveness of Blended Learning as a delivery system for developing Junior High School (JHS) students' knowledge and attitude toward environmental conservation, which is considered an ESD dimension	The study concluded that Blended learning, when infused into JHS science, significantly affects students' knowledge and attitude toward the importance of environmental conservation, a key dimension of ESD
11	Integrating Education for Sustainable Development in Tanzanian Ordinary Secondary School Curriculum: Teachers' Perspectives	The study aimed to explore Tanzanian ordinary secondary school teachers' perspectives on the integration of ESD into their curriculum	Teachers generally have a positive perception of ESD integration, recognizing its role in equipping students with environmental protection skills. However, awareness of specific ESD content varies across subjects, with some teachers expressing concerns about curriculum overload and a lack of sufficient training and materials for effective ESD dissemination

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No	Title	Aim	Finding
12	Philosophy and Practice of Education for Sustainable Development in Ukraine: On the Example of Secondary Education in the Dnipropetrovsk Region	To explore ESD integration in Ukrainian secondary schools, focusing on theoretical foundations, practical implementation, and establishing an ESD-based educational environment.	ESD implementation in the Dnipropetrovsk region successfully fostered positive environmental attitudes and sustainable behaviors among students, parents, and teachers, demonstrating the effectiveness of integrated ESD approaches.
13	Goals and Objectives of Education for Sustainable Development as Modern Curriculum Innovation in Serbia, Montenegro and Croatia	To analyze and compare the goals and objectives of ESD in the curricula of Serbia, Montenegro, and Croatia.	All three countries aim to foster responsible attitudes through ESD. However, Montenegro and Croatia have more comprehensive, interdisciplinary ESD goals, while Serbia's elective course is less globally oriented.
14	STEM Education in Secondary Schools: Teachers' Perspective towards Sustainable Development	To understand Vietnamese secondary teachers' perceptions and application of integrated STEM education to address development challenges and integrate sustainable development concepts.	Teachers hold positive perceptions of STEM as an interdisciplinary, real-world problem-solving approach. They implement constructivist, inquiry-based projects that often integrate multiple STEM disciplines to address SDGs related to environmental pollution, thereby contributing to sustainable development and social equity.
15	Education for Sustainable Development as Diffusion of Innovation of Secondary School Students	To explore the relationship between environmental knowledge, attitudes, and behaviors among junior high school students, considering challenges as moderating factors.	Students have low environmental knowledge but generally positive attitudes and behaviors. Knowledge significantly influences attitudes and behaviors, especially social aspects. Obstacles directly impacted attitudes/behaviors but did not moderate the knowledge-attitude relationship.
16	Pedagogical Approaches for Teaching Education for Sustainable Development in the Technology Education Curriculum	To investigate how Technology Education teachers in Mpumalanga, South Africa, approach ESD teaching, exploring their knowledge, curriculum influences, and pedagogical strategies to bridge the gap between policy and practice.	Teachers understand ESD concepts and curricular opportunities (e.g., project-based learning, Indigenous knowledge, collaborative learning) but face challenges with consistent classroom integration, often relying on demonstrations rather than active ESD pedagogies. There's a significant gap between their knowledge and actual practice.
17	Exploring Green Skills: A Study on the Implementation of Green Skills among Secondary School Students	This study aims to explore secondary school teachers' views on instilling green skills, which are fundamental for sustainable social, economic, and environmental outcomes, and to identify the types of green skills applicable in schools.	Teachers believe green skills should be fostered from the early stages and integrated across subjects, with a focus on practices such as material reuse, waste management, and minimizing electricity and water use. However, challenges include ensuring teacher competency and addressing student diversity in skill application.
18	Integrating sustainable development goals in China's education curriculum: Analysis and future directions	to analyze SDG integration in China's school curriculum and propose future directions.	Increasing SDG integration in PE, Health, and Biology; gaps in Arts, SDG5, and SDG12. Integration is uneven across disciplines
19	Chemistry inquiry conducted by secondary school students into material degradation in the context of sustainability	To evaluate Inquiry-Based Learning (IBL) for secondary students to understand material degradation in a sustainability context, fostering environmental awareness, and implicit green chemistry principles	Students found 100 days insufficient for complete degradation, developed explanatory models, and implicitly applied five green chemistry principles. The IBL approach was well-received, enhancing understanding of degradation, its environmental impact, and sustainability awareness
20	Integrating evidence-based reading practices into middle-school content instruction: exploring a facet of sustainability	To investigate how middle school teachers integrated an evidence-based reading model (CSR) into content instruction, identifying features used, integration depth, and influencing factors for sustainability	Teachers showed varying levels of integration (marginal to high), influenced by their understanding, school support, and fidelity. High integrators consistently embed CSR, viewing it as foundational, while marginal users view it as an add-on. Sustainability was linked to teacher buy-in, contextual adaptation, and systemic support.
21	Go green: evaluating an XR application on biodiversity in German secondary school classrooms	To evaluate a VR application's impact on secondary students' knowledge, interests, and attitudes toward biodiversity and environmental sustainability, compared with traditional lessons.	Both VR and traditional methods increased knowledge, but neither significantly impacted students' interest or attitudes towards environmental issues. School type influenced outcomes, suggesting that VR needs to be tailored for effective ESD.

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No	Title	Aim	Finding
22	Fostering secondary school students' attitudes toward sustainable development and their individual entrepreneurship orientations through a STEM + activity	To introduce a STEM+ entrepreneurship activity for secondary school students, focusing on designing lavender oil cologne, and to assess its impact on students' attitudes toward sustainable development and individual entrepreneurship orientations	The study found a significant increase in secondary school students' attitudes toward sustainable development, with post-test scores being significantly higher than pre-test scores. This positive differentiation was observed across all sub-dimensions: social sustainability, sustainable environment, and sustainable economy, indicating a large effect of the activity
23	School climate assemblies: an educational tool for empowering pupils and youth to take climate and sustainability action	To introduce school climate educational assemblies as an innovative tool for co-creating climate and sustainability solutions, empowering youth, and fostering sustainability competencies.	The intervention achieved high student satisfaction and generated diverse policy recommendations across various environmental areas, demonstrating its effectiveness in fostering sustainability competencies and empowering students as change agents.
24	Teaching controversial sustainability issues at the junior high-school level: an exploratory study of teaching traditions and associations with ways of teaching	To identify teaching traditions for controversial sustainability issues among junior high-school teachers and examine their association with teaching practices, gender, and subject identification.	Four teaching traditions were identified (fact-based science-oriented, fact-based against values, pluralistic, normative), showing significant links to specific teaching practices and variations by gender and subject area
25	Approaching middle-school science student learning and sustainability dilemmas through co-creation processes with science professionals	To explore how middle-school students learn science and address local sustainability dilemmas through co-creation with professionals.	Co-creation on local sustainability dilemmas enhances students' scientific reasoning, engagement, and critical thinking, fostering open-mindedness and curiosity. This approach deepened their understanding of environmental issues and sparked interest in STEM and sustainability.
26	How to Integrate ESD (Education for Sustainable Development) into STEM Education?: A Systematic Literature Review	To identify strategies for integrating ESD concepts into STEM education	Five strategies were found: incorporating SDGs, hands-on projects, real-world problem-solving, fostering partnerships, and providing educator training. These are crucial for preparing students for sustainable development
27	Analysis of the Implementation of Education for Sustainable Development (ESD) Values	To analyze the implementation of ESD values in environmental aspects at Kalirejo 1 Junior High School, a designated Adiwiyata school.	95% of ESD environmental indicators were successfully implemented at Kalirejo 1 Junior High School, integrated into curriculum and school practices, with minor challenges in drainage and water conservation facilities.
28	Assessing secondary level students' critical thinking skills: inspiring environmental education for achieving sustainable development goals	To assess secondary students' critical thinking skills in environmental education for SDGs.	Most secondary students demonstrated weak critical thinking skills in environmental education, underscoring the need for improvement to achieve the SDGs.
29	Development and Validation of an Instrument for Measuring Student Sustainability Competencies	To develop and validate a reliable instrument for assessing student sustainability competencies in secondary schools, aiding in the evaluation of ESD effectiveness.	The 52-item questionnaire developed was reliable and valid for secondary school students. Findings from 1,622 students indicated age and gender differences in competencies, with older students showing more knowledge and girls scoring higher overall.

Source: Researcher, 2025

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