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MORALITY BEFORE KNOWLEDGE

Fostering environmental awareness through education in society to achieve the sustainable development goals: A systematic literature review

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ABSTRACT

Background: This study aims to systematically examine the interconnection between education, environmental awareness, and sustainable development by analyzing 13 empirical articles indexed in Scopus from 2020 to 2025. Previous research has demonstrated that educational approaches integrated with sustainability principles can enhance critical thinking, ecological literacy, and public participation in environmental issues. **Methods:** This study applies a bibliometric and systematic review approach using Scopus data, VOSviewer analysis, and PRISMA guidelines. Articles were screened through defined inclusion criteria, quality appraisal, and thematic coding to synthesize research trends in sustainability education. **Findings:** The synthesis reveals that the implementation of Education for Sustainable Development (ESD) is most effective when experiential learning approaches, such as project-based learning and service learning, are combined with reflections on social values and local contexts. Educators serve as key agents of transformation; however, the success of ESD largely depends on self-efficacy, continuous professional development, and sufficient institutional and policy support. At the institutional level, programs such as adiwiyata schools and green campuses have proven effective in fostering an ecological culture when supported by community participation and systemic policies. Meanwhile, the gap between knowledge and action remains a major challenge in promoting sustainable behavior. **Conclusion:** This review concludes that education holds strategic potential as a catalyst for social transformation when supported by adaptive policies, long-term evaluation, and cross-sector collaboration. **Novelty/Originality of this article:** The novelty of this study lies in the integration of bibliometric analysis and systematic review to map global research patterns on environmental awareness education, providing a comprehensive understanding of education's role as a driving force for sustainability within the SDGs framework.

KEYWORDS: environmental awareness; education; society; sustainable development.

1. Introduction

Education plays a crucial role in achieving the Sustainable Development Goals (SDGs) (Bui et al., 2024; Kioupi & Voulvoulis, 2022; Okubo et al., 2021), particularly by strengthening public awareness and behavior toward environmental issues (Leal et al., 2024; Sharma et al., 2023). The SDG agenda explicitly emphasizes the importance of education in shaping citizens who possess the competencies necessary to support global sustainability. In this context, education is not merely intended to transfer knowledge but also to cultivate critical thinking, ecological empathy, and concrete sustainable actions (Amprazis & Papadopoulou, 2025; Arbues & Celaya, 2025; Onbaşılı & Yalman, 2025). One

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of the most relevant approaches in supporting this agenda is Education for Sustainable Development (ESD), which aims to integrate sustainability principles into cross-disciplinary learning processes, including science and STEM education (Acosta-Castellanos & Queiruga-Dios, 2022; Castellanos et al., 2021). STEM-based learning combined with sustainability values has been shown to enhance students' understanding of environmental issues and foster active engagement in solving real-world problems (Alkair et al., 2023; Cordaro et al., 2025; Li, 2025).

In several contexts, this integration even strengthens scientific literacy while cultivating critical ecological awareness (Al-Barakat et al., 2025; Guerrero & Sjöström, 2025). However, the success of ESD implementation largely depends on educators' capacity. Pedagogical competence, attitudes toward environmental issues, and teachers' self-efficacy are crucial factors in realizing meaningful ESD practices (Boeve-de Pauw et al., 2022; Handtke et al., 2022; Karvonen et al., 2023). Research indicates that although most teachers hold positive attitudes toward sustainability education, many feel unprepared or lack sufficient training to integrate ESD into their teaching (Boeve-de Pauw et al., 2022). This highlights the importance of continuous professional development and strong institutional support for educators. Educational institutions, both at school and university levels, along with government policy support, form an essential ecosystem for promoting ESD (Fia et al., 2023; Price et al., 2021; Žalėnienė & Pereira, 2021). Programs such as adiwiyata schools, green campuses, and the integration of SDGs into national curricula exemplify how policy initiatives can foster a culture of sustainable learning (Megawati et al., 2022; Zhu et al., 2024). Nonetheless, many of these initiatives remain symbolic and lack significant structural change (Husin et al., 2025). Thus, synergy between regulation, school leadership, community participation, and adaptive curricula is essential to achieve genuine transformation.

Education is also expected to bridge the knowledge–action gap (Kirby & Zwickle, 2021; Schönstein & Budke, 2023). Although environmental literacy is improving, it does not always translate into long-term behavioral change (Feldbacher et al., 2024). Experience-based interventions, community participation, and value reflection have proven more effective in building learners' intrinsic motivation for pro-environmental action (Douglas et al., 2024; Uzorka et al., 2024). This underscores the importance of designing learning experiences that are not only informative but also emotionally and socially transformative. In Indonesia, various initiatives have been implemented in environmental education, both through formal programs such as Adiwiyata program and the national curriculum, which increasingly incorporates SDG-related aspects (Megawati et al., 2022). owever, challenges remain, particularly concerning policy alignment, teacher competence, and program sustainability (Corres et al., 2024). In this context, a systematic review of best practices and barriers in ESD implementation is essential to guide more effective educational policies and strategies. Given this background, a deeper understanding is needed of how Education for Sustainable Development (ESD) is implemented across diverse educational contexts. Therefore, reviewing previous studies is crucial to explore the approaches, challenges, and opportunities for integrating sustainability values into educational practices.

Environmental awareness encompasses knowledge, attitudes, and active public participation in maintaining ecosystem sustainability. Education plays a pivotal role in nurturing this awareness (Husin et al., 2025; van de Wetering et al., 2022). For instance, Sihombing et al. (2024) emphasized that educational institutions—from early childhood to higher education—are essential in disseminating sustainability knowledge and fostering environmental responsibility through community engagement. With contextual and participatory educational approaches, individuals of all ages can be equipped to take pro-environmental actions within their communities (Prada da Silva et al., 2025; Rushton et al., 2024). Nevertheless, Zhang & Cao (2025) identified a gap between increased environmental awareness and concrete pro-environmental behaviors among students, suggesting that awareness does not always translate into immediate action. Hence, effective educational strategies are required to bridge this gap.

Education provides a framework for shaping environmentally responsible behavior through both knowledge transfer and value formation. The concept of Education for Sustainable Development (ESD) is explicitly designed to promote sustainable behavior (Günther et al., 2022). Zhang & Cao (2025) assert that ESD is a transformational pedagogical approach that integrates critical thinking with environmental responsibility. By equipping learners with knowledge, skills, values, and attitudes that support social, economic, and ecological balance, ESD empowers individuals to make sustainable decisions (Amprazis & Papadopoulou, 2025; Hanisch & Eirdosh, 2023). Research also indicates that psychological factors—such as environmental attitudes, self-efficacy, and social norms—play a key role in linking education to pro-environmental actions (Helferich et al., 2023; Zhang & Cao, 2025). For example, higher environmental self-efficacy (individual belief in the ability to perform pro-environmental actions) has been shown to predict recycling and energy conservation behaviors (Zhang & Cao, 2025). hus, education must go beyond information transmission to foster positive attitudes and confidence in individual agency to drive behavioral change.

ESD is a holistic educational approach that regards education as a key instrument for achieving the Sustainable Development Goals (SDGs) (Xuan & Lindqvist, 2025; Robertson et al., 2025). It promotes an understanding of the interdependence between humans and nature and supports the development of just and inclusive societies. ESD empowers learners with the knowledge, skills, values, and capacities needed to make informed decisions and act responsibly to protect the environment. Historically, ESD evolved from over four decades of environmental education, beginning with the Tbilisi Declaration (1977), which emphasized the human–nature connection. Its implementation involves curriculum reform, innovative teaching methods, and supportive learning environments. Many countries are still developing their ESD policy frameworks; some have integrated ESD into national education policies, though challenges related to resources and policy support persist (Hargreaves, 2008). In Indonesia, Sihombing et al. (2024) highlight the need to shift from an economic growth–oriented education paradigm to one centered on sustainable learning. In other words, ESD integrates global issues—such as climate change and biodiversity—into learning processes to prepare students for complex future challenges.

Integrating ESD into the STEM curriculum (Science, Technology, Engineering, and Mathematics) has become a major trend for strengthening sustainability literacy (Djam'an, 2025; Fathurohman et al., 2023; Sanchez et al., 2025). A systematic review by Sihombing et al. (2024) reports that STEM-ESD has been widely implemented in Indonesian education, significantly improving students' sustainability awareness and critical thinking abilities. Effective instructional approaches include project-based learning, STEM modules linked to SDG principles, and inquiry-based methods. Furthermore, STEM-ESD explicitly supports SDG achievement by equipping learners with interdisciplinary problem-solving skills (Fathurohman et al., 2023). For example, through STEM-ESD, students not only learn scientific and mathematical concepts but also apply them to local contexts—such as clean water management or sustainable urban solutions—thereby developing a solution-oriented mindset toward environmental challenges (Sihombing et al., 2024). However, challenges remain, including the dominance of traditional scientific perspectives and the lack of integrated teaching materials, which hinder a more holistic application of ESD.

The role of educators as change agents is critical in ESD (Berglund et al., 2025; Ghamrawi et al., 2025). Teacher literacy in sustainability includes deep knowledge, pedagogical skills, and positive attitudes toward environmental values (Boeve-de Pauw et al., 2022; Sanchez et al., 2025; Xiong et al., 2025). Frameworks such as those developed by UNESCO and UNECE highlight these three aspects, emphasizing teachers' self-efficacy—their confidence in teaching sustainability effectively Daumiller et al. (2025) found that teachers with high self-efficacy are more persistent, open to innovative teaching strategies, and more likely to integrate sustainability issues into classroom practice. Moreover, teachers' personal engagement in environmentally friendly behaviors enhances their authenticity and motivation. Conversely, limited pedagogical confidence and lack of knowledge often impede ESD implementation (Herranen & Aksela, 2024; Parry & Metzger, 2023). Therefore, continuous professional development and the design of training

programs that strengthen both cognitive and affective aspects (attitudes and values) are crucial for empowering teachers as sustainability educators.

The implementation of ESD depends not only on teachers and students but also on institutional and policy support (Müller et al., 2021). UNESCO advocates a whole-institution approach to ensure that sustainability permeates all aspects of education, including management, operations, and community engagement. At the systemic level, Sihombing et al. (2024) emphasize the need for policy reforms that support interdisciplinary curricula, teacher training, and comprehensive integration of sustainability concepts within STEM education. The involvement of international organizations and local communities also plays a pivotal role in building a mutually reinforcing ESD ecosystem. Through the synergy of pro-ESD policies and educational practice, learning can move beyond theory to promote tangible action toward sustainable development.

Therefore, to address the complexity and diversity of ESD implementation approaches, this study adopts a Systematic Literature Review (SLR) method. This approach was chosen due to the growing number of publications from 2020 to 2025 and the limited number of studies that comprehensively compare ESD implementation across educational contexts, institutional levels, and behavioral or policy dimensions (Boeve-de Pauw et al., 2022). Moreover, many studies remain fragmented, focusing on a single dimension—such as teacher attitudes or curriculum design—without connecting them to broader structural and collective behavioral transformations (Husin et al., 2025). Ence, this review synthesizes recent empirical literature indexed in Scopus over the past five years (2020–2025) to provide a holistic understanding of the interrelation between education and environmental awareness in achieving the SDGs. Based on the above background and literature review, this study seeks to address six main research questions: What are the publication trends concerning the impact of education on environmental awareness? What are the clusters and keywords associated with research on education and environmental awareness? How is ESD implemented within STEM and science education? What are the competencies, attitudes, and self-efficacy of educators in ESD? What roles do institutions and policies (schools, universities, and governments) play as ESD ecosystems? How are environmental awareness, behavior, and value transformation developed through education?

2. Methods

2.1 Study design and identify the purpose

This study employs Passas (2024) bibliometric analysis to identify research trends and clusters on the topic, while following the systematic review steps proposed by Okoli (2015). In addition, the author adheres to key procedures from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021). To ensure the relevance of the discussion and findings, the analysis utilizes VOSviewer version 1.6.20 as the primary data processing tool (for identification and network analysis) using data extracted from the Scopus database. Complementary bibliometric analysis was also conducted using the "search result analysis" feature on scopus.com. For the systematic review component, the study follows the three-stage framework proposed Okoli (2015) for conducting a comprehensive and reliable systematic literature review. the framework consists of the following stages: identify the purpose, draft protocol and train the team, apply practical screen, search for literature, extract data, appraise quality, synthesize studies, and write the review.

Given the critical role of education in shaping environmental awareness and practices that support the achievement of the Sustainable Development Goals, and considering the diversity of pedagogical approaches (such as service learning, project-based learning, and green school programs) that have been developed—often without long-term evidence, clear competency indicators, or consistent implementation—this review aims to systematically: Identify the most effective pedagogical approaches for linking knowledge, affect, and pro-environmental action; Assess educators' readiness, capacity-building needs, and

institutional barriers; Evaluate the roles of institutions and policy frameworks in ensuring the continuity of ESD initiatives; and Reveal methodological gaps to formulate actionable recommendations and future research agendas for policymakers, educational leaders, curriculum developers, practitioners, and researchers.

2.2 Draf protocol and train the team and apply practical screen

Since the writing and analysis of this article were conducted by a single researcher, no formal agreement or protocol was established. However, a systematic workflow was designed as a structured reference for the research process. The steps undertaken include identifying articles related to environmental awareness, education, and SDGs, analyzing key findings from selected articles, developing an outline, synthesizing results, and compiling the final research findings. The screening stage aims to accurately filter the articles obtained during the search process and select empirical studies that specifically examine the role of education in fostering environmental awareness for sustainable development. This process ensures that the selected studies align with the research questions and objectives of this review. Table 1 summarizes the inclusion and exclusion criteria applied in the study selection process.

Table 1. Inclusion and exlusion criteria for article selection

Criterion	Inclusion	Exclusion
Article topic	Incorporate education and environmental awareness within the framework of sustainable development (ESD).	Do not address education or environmental awareness in the context of sustainable development.
Article type	Empiracal research articles and conference papers	Review papers, book, and book chapter.
Article publication	Published and peer-reviewed.	Unpublished, non–peer-reviewed, or preprint sources.
Article availability	Available in full-text format and accessible.	Inaccessible or abstract-only sources.
Article language	Written in English.	Non-English publications.

2.3 Search for literature

We conducted a comprehensive literature search to identify articles that explore, examine, and discuss the integration of education and environmental awareness within the framework of sustainable development (ESD). Two research databases were employed, with Scopus selected as the primary source due to its comprehensive coverage and its recognition as one of the most reputable databases across various academic disciplines. The Scopus database provides extensive bibliographic data, enhancing research accuracy and supporting robust conclusions. To locate and identify relevant articles, the following search formula was applied: (TITLE-ABS-KEY (“Environmental Awareness”) AND TITLE-ABS-KEY (education) AND TITLE-ABS-KEY (society) AND TITLE-ABS-KEY (“sustainable development”)) AND PUBYEAR > 2018 AND PUBYEAR < 2026.

This search, conducted on October 15, 2025, initially yielded 113 articles using the keywords “Environmental Awareness,” “Education,” “Society,” and “Sustainable Development.” To ensure the focus remained on recent research, the selection was limited to studies published within the last five years (2020–2025), reducing the results to 64 articles. These records were analyzed using the “Search Results Analysis” feature on scopus.com. In addition, all retrieved data were exported into CSV (Excel) files, which were subsequently processed and examined using VOSviewer version 1.6.20 for bibliometric mapping and visualization. A systematic screening process was then applied to all retrieved articles, using clearly defined inclusion and exclusion criteria (as summarized in Table 1). Articles meeting any exclusion criterion were removed, resulting in 32 eligible studies. Following a detailed review, 16 articles were excluded for being outside the educational

context, leaving 16 articles for in-depth analysis. The overall review and selection process is illustrated in Figure 1.

2.4 Quality appraisal

The assessment and evaluation of the quality of extracted articles followed the procedures outlined by Page et al. (2021). ccordingly, the selected studies were rigorously evaluated using Fink (2019), which emphasize the need for detailed descriptions of the research background, problem themes, methodology, instruments, analysis, results, conclusions, strengths, and limitations. The quality appraisal began with a comprehensive assessment of each study's design, data collection methods, and analytical procedures to ensure methodological rigor and alignment with the review's objectives. During this stage, three articles were excluded for being outside the analytical scope. Consequently, 13 articles were retained and analyzed comprehensively and critically for inclusion in this systematic review

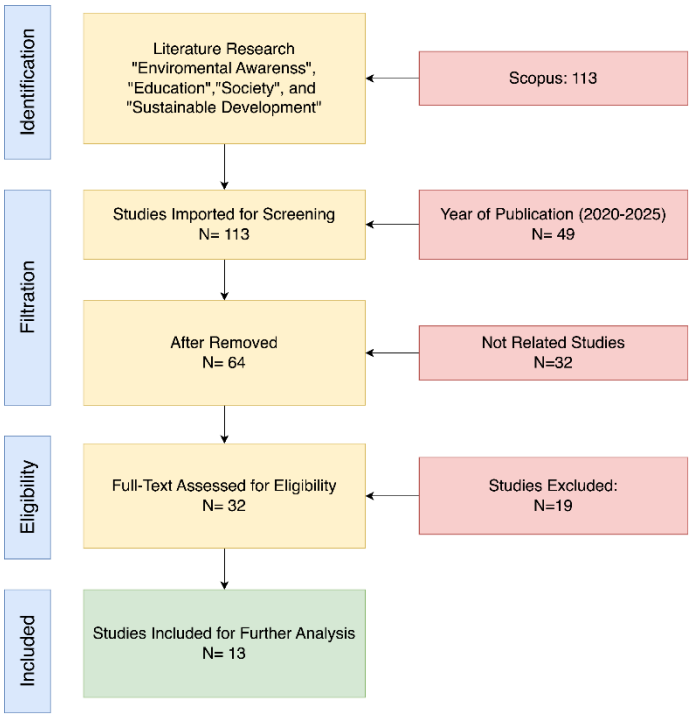

Fig. 1. Article selection procedure (PRISMA)

2.5 Data extraction and synthesize studies

The next step was data extraction, which involved retrieving key information from the 13 selected articles. Following Creswell (2014) coding technique, the process was carried out in three stages: Open coding, to identify and label the main ideas within each article; Axial coding, to categorize and establish relationships among emerging concepts; and Selective coding, to synthesize and formulate the core themes. The detailed coding process and analytical descriptions are presented in Table 2.

This stage was carried out by integrating the key facts and main findings from the thirteen empirical studies that examined the implementation of Education for Sustainable Development (ESD) across various contexts, including STEM learning, teacher training, institutional policies, and eco-school programs. The analysis employed a qualitative thematic approach, in which each study was coded, categorized, and compared based on similarities and differences in focus, methods, and outcomes. This approach enabled the identification of cross-article patterns, relationships between variables (for instance, between experiential pedagogy and behavioral change), as well as conceptual debates (such

as those between local contextualization and global standardization). Thus, this analytical phase not only consolidated diverse research findings but also produced a discursive synthesis that comprehensively highlights trends, gaps, and future directions in sustainability education.

Table 2. Description of unit analysis

Unit of analysis	Section under analysis	Coding
Implementation of ESD in STEM and Science Education	Theorical Framework, Discussion, and Conclusion	Positif Critical Spesifik Conceptual
Competence, Attitudes, and Self-Efficacy of Educators in ESD	Discussion and Conclusion	Positif Spesifik Structural Contextual Integrative
Institutions and Policies: Schools, Universities, and Governments as ESD Ecosystems	Theorical Framework, Discussion and Conclusion	Systemic Positive Structural
Environmental Awareness, Behavior, and Value Transformation	Discussion, and Conclusion	Negative Positive Conceptual Spesfic Method

3. Results and Discussion

3.1 Result

3.1.1 Analyze results

The analysis initially included 64 Scopus-indexed articles, which were examined in terms of publication year, document type, authorship, and other bibliometric aspects using Scopus analytical features.

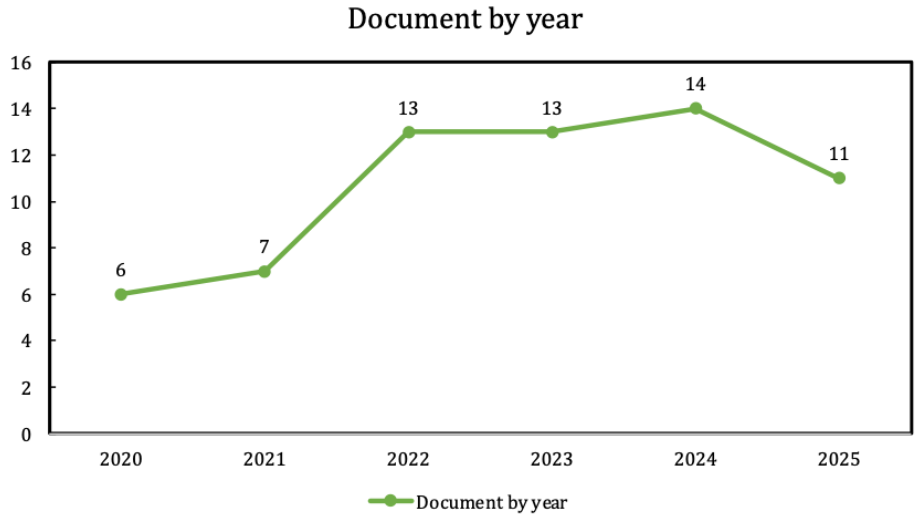

Fig. 2. Publication trends for the keywords “Environmental Awareness,” “Education,” “Society,” and “Sustainable Development” (2020–2025)

Figure 2 shows a steady increase in publications related to “Environmental Awareness,” “Education,” “Society,” and “Sustainable Development” from 2020 to 2024, followed by a slight decrease in 2025. Publications grew from six in 2020 to a peak of fourteen in 2024,

suggesting heightened scholarly attention during this period. The minor decline in 2025 may indicate a thematic shift or publication lag rather than a reduction of interest.

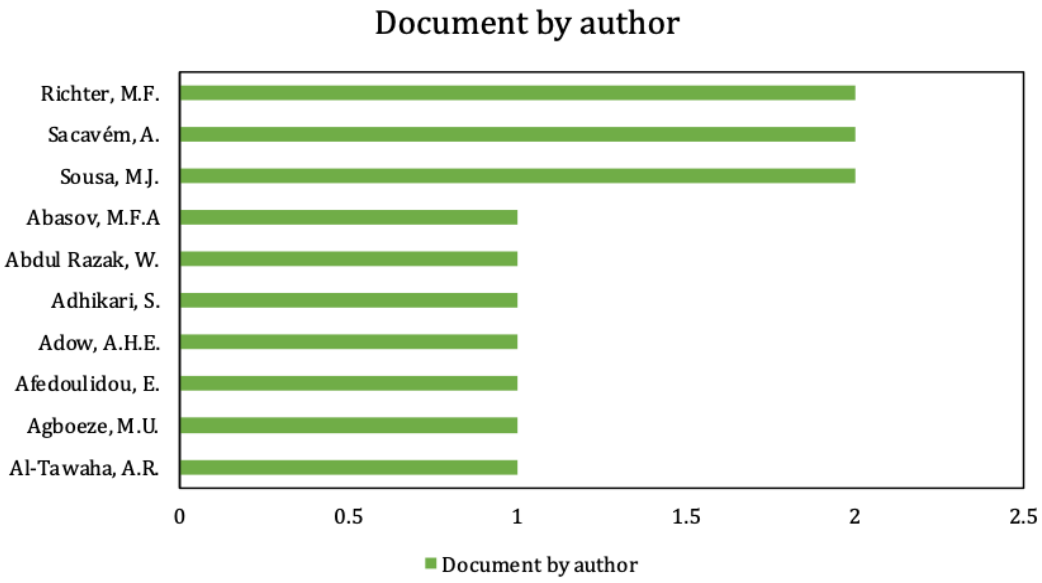

Fig. 3. Top 10 authors

Figure 3 indicates a dispersed authorship pattern: only three authors contributed more than once, while most published a single paper. This dispersion reflects the interdisciplinary and collaborative nature of sustainability education research. Further co-authorship and institutional network analyses are recommended to explore potential research leadership patterns. The following figure presents the publication distribution by country (Figure 4).

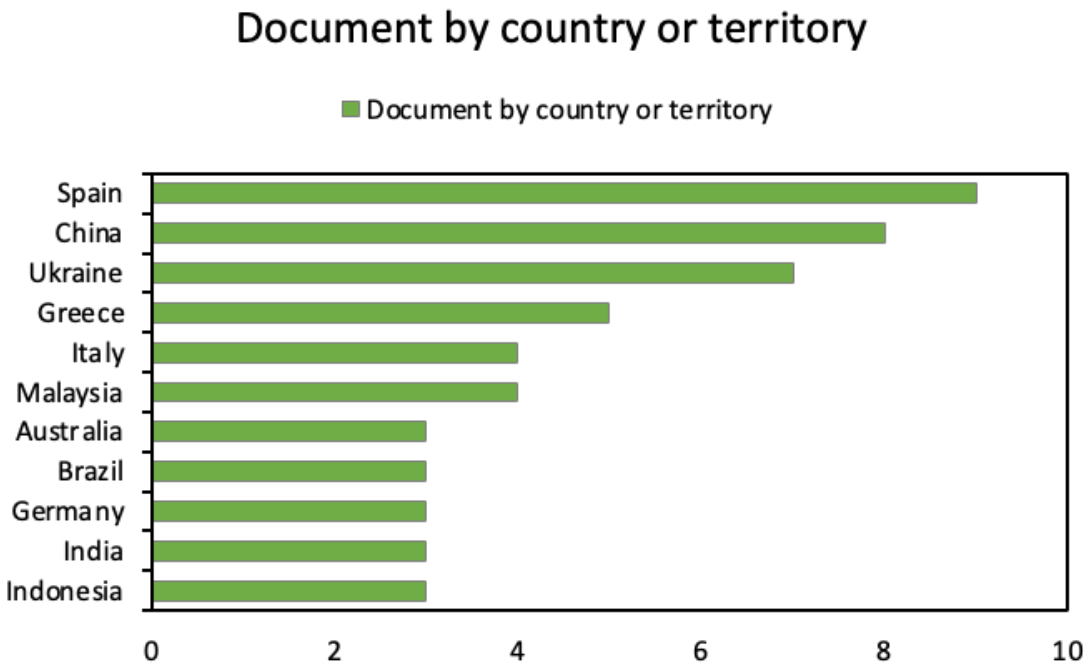

Fig. 4. Top 10 countries by publication output

Figure 4 reveals that Spain produced the most publications, followed by China and Ukraine, while countries such as Greece, Italy, Malaysia, and Indonesia contributed moderately. This distribution highlights the concentration of research output in a few nations with strong sustainability policies and international collaborations.

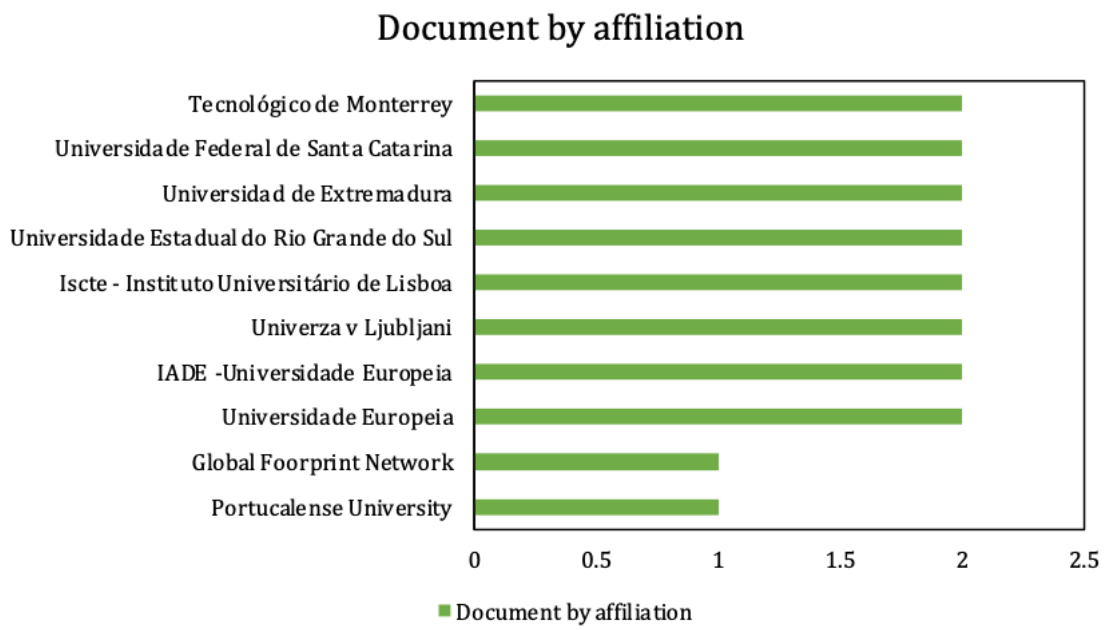

Fig. 5. Top 10 affiliations by publication output

Figure 5 further shows balanced institutional participation, with no single university dominating the field. European and Latin American universities are especially active, indicating strong regional research networks and increasing policy engagement beyond academia.

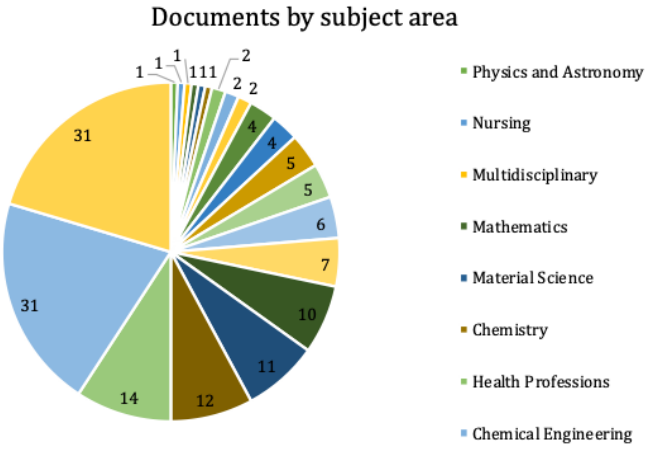

Fig. 6. Documents by subject area

Publications on the topic are most frequent in the Environmental Sciences and Social Sciences, followed by contributions from Engineering, Computer Science, and Energy. This confirms the multidisciplinary nature of sustainability research, integrating social, technical, and policy dimensions. Overall, publication activity increased steadily until 2024, reflecting broad interdisciplinary collaboration and growing recognition of education as a driver of sustainable development. Although output slightly decreased in 2025, the trend underscores continuous global engagement with environmental education research.

3.1.2 Analysis bibliometric

A bibliometric network analysis was conducted using VOSviewer to identify clusters and relationships among keywords extracted from the Scopus dataset. Figure 7 presents the network visualization, positioning “sustainable development” as the central node connected

to clusters such as “environmental awareness,” “education,” and “policy.” This structure highlights the interdisciplinary and interconnected nature of sustainability education research.

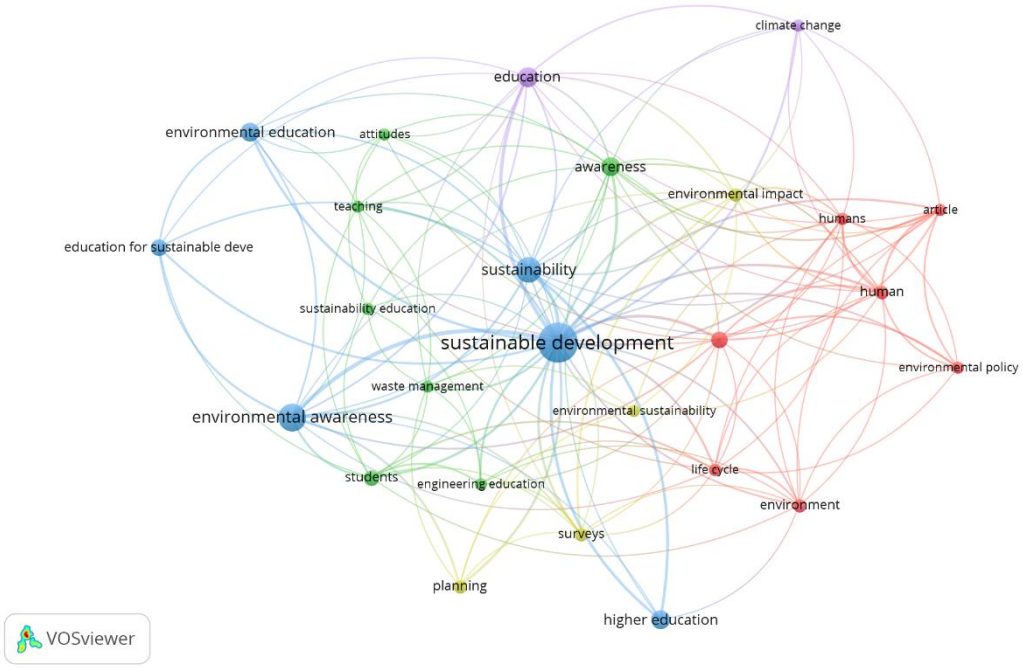

Fig. 7. Network visualization

Figure 7 displays the VOSviewer network mapping, positioning “sustainable development” as the central node of the research network, connected to major clusters such as “environmental awareness,” “education,” and “policy.” The map highlights the interdisciplinary character of research that integrates pedagogical, policy, and technical evaluation dimensions within the sustainability context. Co-occurrence analysis indicates strong interlinkages among education, human behavior, and environmental policy. Two major opportunities emerge: (1) the need for longitudinal studies to assess the long-term impact of education on environmental behavior, and (2) the integration of technical and social approaches to strengthen evidence-based policymaking. Specific cluster details are presented in Table 3.

Table 3. Claster

Color	Claster
Red (5)	article, enviroment, enviromental policy, enviromental protection, human, humans, life cycle.
Green (7)	attitudes, awareness, engineering education, students, sustainability education, teaching, waste management.
Blue (6)	education for sustainable development, enviromental awareness, enviromental education, higher education, sustainability, sustainability development
Yellow (4)	enviromental impact, enviromental sustainablity, planning, surverys
Purple (2)	climate change, education.

Figure 8 depicts the chronological evolution of research themes, showing that early studies (2020–2022) emphasized formal education and sustainability values, while later works (2023–2024) expanded toward policy and social practice.

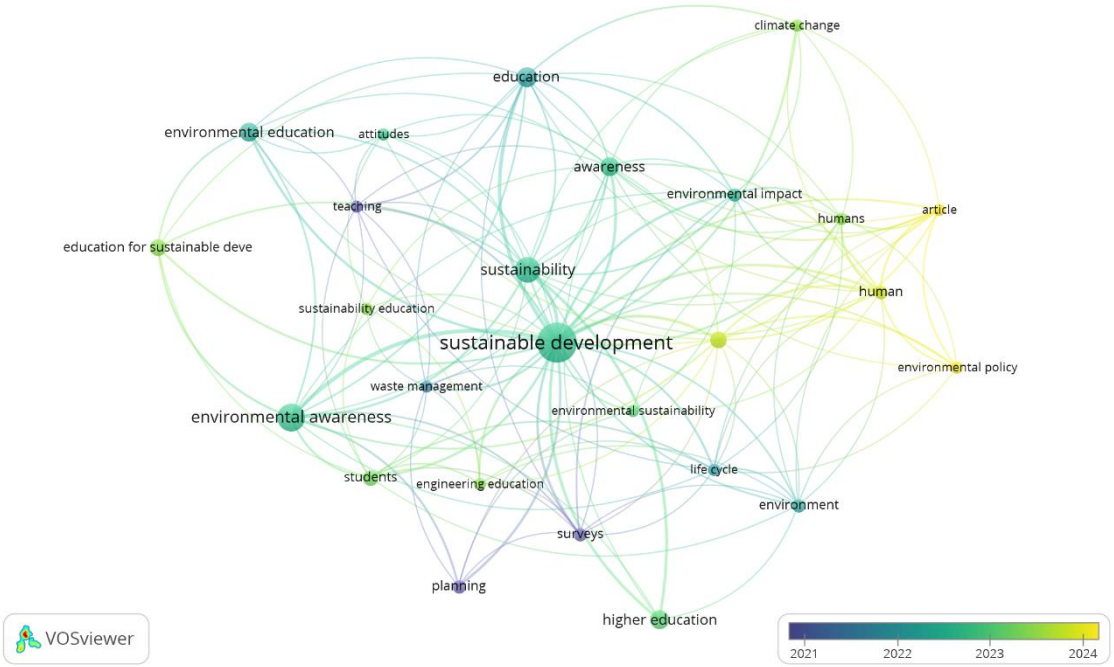

Fig. 8. Overlay visualization

Figure 9 reinforces this shift: "sustainable development" appears as the densest node, confirming its central role in global academic discourse. The growing inclusion of "higher education" and "environmental policy" keywords reflects a transition from theoretical exploration to applied and institutionalized sustainability education. Additionally, topics such as "higher education" and "environmental policy" indicate an expansion of research focus from theoretical discussions toward practical implementation through policy and formal education. Overall, this trend reflects an increasingly integrative and progressive direction of research, positioning education as a key driver in building a cross-disciplinary knowledge ecosystem aimed at achieving the Sustainable Development Goals (SDGs).

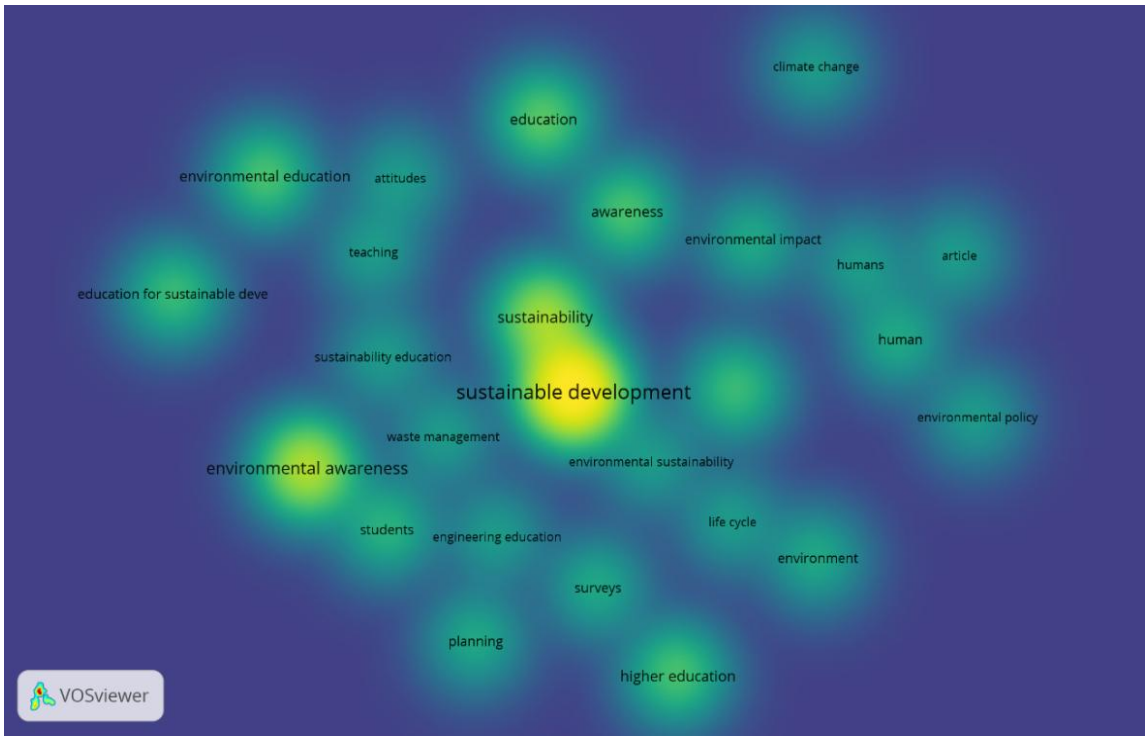

Fig. 9. Density visualization

3.1.3 Main findings of the reviewed studies

This section synthesizes answers to the six research questions and presents the principal findings derived from the 13 reviewed studies, summarized in Table 4. Based on Table 4, the thirteen reviewed articles demonstrate significant diversity in geographical contexts, educational levels, and methodological approaches in implementing Education for Sustainable Development (ESD) across various global education systems. The studies span Europe, Asia, and Africa, covering levels from early childhood to higher education, and employing qualitative, quantitative, experimental, and mixed-method designs. This diversity provides a strong empirical foundation for understanding the strategies, challenges, and effectiveness of ESD in integrating sustainability into curricula, teacher training, and interdisciplinary learning toward the achievement of the SDGs. The synthesized results are presented as follows.

Table 4. Article

No	Author	Year	Country	Educational level	Method
01	Petkou et al.	2025	Greece	Early Childhood Education	Qualitative
02	Cherniakova et al.	2025	Ukraine	All levels (curriculum integration)	Qualitative
03	Yusupova et al.	2025	Uzbekistan	Higher Education	Mix-Method
04	Li & Eilks	2024	China & Germany	Secondary Education	Teaching intervention
05	Mospan	2024	Ukraine	Higher Education (Teacher & Economics)	Survey
06	Zinchenko et al.	2024	Ukraine & Azerbaijan	Higher Education	Qualitative
07	Álvarez-Nieto et al.	2024	Spain	Higher Education (Nursing degree)	Quasy-experimental
08	Mondragon et al.	2023	Spain	Higher Education	Quantitative
09	Martín-Sánchez et al.	2022	Spain	Higher Education (STEM Education)	Experimental
10	Megawati et al.	2022	Indonesia	Secondary & High School	Qualitative
11	Tunji-Olayeni et al.	2023	Nigeria	Higher Education (Construction Education)	Quantitative
12	Bezeljak et al.	2020	Austia & Slovenia	Higher Education (Pre-service teacher education	Mix-method
13	Martínez-Borreguero et al.	2020	Spain	Higher Education (Teacher education for Primary & Secondary)	Mix-method

3.1.4 Implementation of ESD in STEM and science education

The pedagogical shift toward Education for Sustainable Development (ESD) within STEM contexts is most evident in the consistent finding that experience-based learning approaches—such as service learning and project-based learning—are effective in enhancing students' understanding of the SDGs, problem-solving abilities, and motivation to take action (Martín-Sánchez et al., 2022; Mospan, 2024; Petkou et al., 2025). Interventions that combine technical tasks with ethical reflection encourage learners to connect scientific theories with socio-environmental consequences, resulting in more meaningful learning experiences (Martín-Sánchez et al., 2022; Mospan, 2024; Petkou et al., 2025). Moreover, evidence shows that when projects are community-centered, their effects extend beyond the classroom into the surrounding social environment (Megawati et al., 2022; Yusupova et al., 2025).

However, the integration of local cultural values as an entry point to ESD remains a subject of debate. While cultural contextualization can enhance the relevance and acceptance of learning materials (Cherniakova et al., 2025; Li & Eilks, 2024), some scholars argue that emphasizing local values without strengthening scientific literacy may weaken

learners' analytical and technical capabilities (Li & Eilks, 2024; Tunji-Olayeni et al., 2023). Thus, the best practice recommended is to combine local values with scientific standards rather than privileging one over the other, ensuring that STEM-based ESD remains both credible and contextually relevant (Li & Eilks, 2024; Martín-Sánchez et al., 2022; Tunji-Olayeni et al., 2023). Current curricula still tend to position sustainability as an additional topic rather than as a central conceptual framework for STEM education. Consequently, many graduates understand environmental concepts but struggle to apply them in professional practice (Mospan, 2024; Tunji-Olayeni et al., 2023). For example, research involving construction students reveals a gap between environmental awareness and practical eco-friendly skills (Tunji-Olayeni et al., 2023). Therefore, curriculum reorientation is needed so that ESD becomes an integral component in shaping STEM learning objectives (Mospan, 2024; Tunji-Olayeni et al., 2023).

Methodologically, most ESD-STEM studies use pre-post or short-term case study designs, leaving limited evidence on long-term professional behavioral change (Martín-Sánchez et al., 2022; Mospan, 2024; Petkou et al., 2025). As a result, claims of broader cultural transformation require validation through longitudinal studies and clear behavioral indicators (Martín-Sánchez et al., 2022; Petkou et al., 2025; Tunji-Olayeni et al., 2023). Some recent articles have proposed sustainability literacy metrics, yet no consensus has been established regarding measurement standards (Bezeljak et al., 2020; Tunji-Olayeni et al., 2023). In summary, ESD integration within STEM education is most effective when it is cohesive and holistic, combining action-oriented pedagogy that demands technical application, strengthened scientific literacy to ensure evidence-based reasoning, and value reflection that links action to social ethics. This blended model is widely recommended across studies (Li & Eilks, 2024; Martín-Sánchez et al., 2022; Mospan, 2024; Petkou et al., 2025; Tunji-Olayeni et al., 2023).

3.1.5 Educators' competence, attitudes, and self-efficacy in ESD

Educators and pre-service teachers consistently emerge as key agents in the transformation of ESD. Most studies highlight teachers' positive attitudes toward sustainability education but also reveal a lack of practical capacity to implement it effectively in classrooms (Álvarez-Nieto et al., 2024; Bezeljak et al., 2020; Martínez-Borreguero et al., 2020; Zinchenko et al., 2024). Positive attitudes are an important foundation; however, without specific pedagogical skills in ESD, classroom practices tend to be sporadic and less impactful (Martínez-Borreguero et al., 2020; Zinchenko et al., 2024). Research evaluating training programs indicates that normative instruction alone is insufficient—field experience is essential for developing self-efficacy (Bezeljak et al., 2020; Martínez-Borreguero et al., 2020). Teachers' self-efficacy—their belief in their ability to teach ESD—improves significantly through experiential learning, structured practice, and field-based modules (Martín-Sánchez et al., 2022; Petkou et al., 2025). Studies on pre-service biology teachers in Europe show that while they understand environmental aspects, they often struggle to connect them with socio-economic issues, suggesting that teacher training should broaden competencies rather than merely expand content (Bezeljak et al., 2020). Institutional support in the form of time, resources, and recognition is also crucial for maintaining self-efficacy and ensuring sustainable practice (Martínez-Borreguero et al., 2020; Zinchenko et al., 2024).

Structural barriers frequently reported include curriculum overload, limited time, and insufficient facilities or incentives for teachers to develop ESD materials in depth (Álvarez-Nieto et al., 2024; Zinchenko et al., 2024). In some Adiwiyata school contexts, teachers who receive adequate space and institutional support become effective community change agents, indicating that institutional structures can enhance individual capacity (Cherniakova et al., 2025; Megawati et al., 2022; Yusupova et al., 2025). Conversely, in the absence of such support networks, teachers' initiatives tend to fade quickly. Gender and contextual disparities are also relevant: some studies find that female teachers tend to show stronger environmental commitment, while urban–rural differences and resource

availability affect implementation capacity (Martínez-Borreguero et al., 2020; Yusupova et al., 2025). Therefore, capacity-building programs must be both gender-sensitive and contextually adaptive. In conclusion, the literature underscores the need for hybrid teacher education reform—combining ESD-specific pedagogical content knowledge (PCK), action-based experience, critical reflection, and institutional support—to transform self-efficacy into consistent and impactful classroom practice (Álvarez-Nieto et al., 2024; Bezeljak et al., 2020; Martín-Sánchez et al., 2022; Martínez-Borreguero et al., 2020; Petkou et al., 2025; Zinchenko et al., 2024).

3.1.6 Institutions and policies: Schools, universities, and governments as ESD ecosystems

Eco-school programs such as Adiwiyata exemplify how local policy, leadership, and community participation can transform environmental initiatives into school-wide cultural practices (Cherniakova et al., 2025; Megawati et al., 2022; Yusupova et al., 2025). The AGIL framework highlights four necessary social functions—adaptation, goal attainment, integration, and latency (value maintenance)—to ensure that ESD programs become part of an institution's identity rather than isolated activities (Cherniakova et al., 2025; Megawati et al., 2022). When these factors align, ecological literacy and community engagement increase significantly (Megawati et al., 2022; Yusupova et al., 2025). At the university level, green campus initiatives and ESD integration demonstrate potential as laboratories for social and environmental innovation, enabling institutions to produce research, curricula, and graduates who transfer sustainable practices into industry and society (Martín-Sánchez et al., 2022; Petkou et al., 2025). owever, the link between academia and professional practice remains suboptimal—studies of construction students reveal that environmental awareness does not automatically translate into applied competence (Tunji-Olayeni et al., 2023). Stronger collaboration between universities and industry actors is therefore essential.

Formal education policies often include the SDGs in principle but fall short in implementation, lacking operational indicators, resources, and accountability mechanisms (Bezeljak et al., 2020; Mospan, 2024; Zinchenko et al., 2024). Consequently, some initiatives end at certification or "green labeling" stages without structural transformation (Megawati et al., 2022; Yusupova et al., 2025). Clear resource allocation and long-term monitoring systems are needed to address this issue. Policy debates also arise regarding the balance between global competence standards and local adaptation. Some studies advocate for measurable global frameworks to ensure ESD quality across nations (Bezeljak et al., 2020), while others emphasize local contextualization to prevent cultural imposition (Cherniakova et al., 2025; Li & Eilks, 2024). The synthesis recommends a "glocal" approach—flexible core standards adapted to local contexts. Ultimately, the sustainability of ESD requires multi-level synergy—alignment between national policy, institutional curricula, and school-level practice, supported by industry and community partnerships (Cherniakova et al., 2025; Megawati et al., 2022; Mospan, 2024; Petkou et al., 2025; Tunji-Olayeni et al., 2023; Yusupova et al., 2025). Without this coordination, promising initiatives are unlikely to endure once external support diminishes.

3.1.7 Environmental awareness, behavior, and value transformation

The reviewed studies reaffirm the existence of the knowledge–action gap: environmental literacy tends to increase pro-environmental attitudes but does not always lead to sustained behavioral change (Álvarez-Nieto et al., 2024; Martínez-Borreguero et al., 2020). Behavioral assessments are often limited to short-term evaluations, making it difficult to determine whether interventions foster lasting habits. This highlights the need to focus on affective (emotional and empathetic) dimensions and social structures that support sustained action (Martínez-Borreguero et al., 2020; Yusupova et al., 2025). Action-based approaches—such as waste management projects, community engagement activities, and energy-saving initiatives—have proven effective in narrowing this gap, as learners

practice real decision-making and experience the consequences of their actions (Martín-Sánchez et al., 2022; Mospan, 2024; Petkou et al., 2025). Community participation and social recognition (e.g., school awards or citizen involvement) also reinforce behavioral internalization (Cherniakova et al., 2025; Megawati et al., 2022; Yusupova et al., 2025). Nonetheless, evidence of long-term behavioral stability remains limited (Martín-Sánchez et al., 2022; Petkou et al., 2025; Tunji-Olayeni et al., 2023).

The affective dimension plays a crucial mediating role: positive emotions, a sense of responsibility, and self-efficacy significantly increase the likelihood of sustained sustainable behavior (Martínez-Borreguero et al., 2020). Effective interventions combine cognitive learning with emotional experiences—such as meaningful collaborative activities—to foster intrinsic motivation rather than mere instrumental compliance. Theoretical tensions persist between the universality of sustainability values and contextual needs. Some scholars advocate for global standards to facilitate measurement (Bezeljak et al., 2020), while others stress the importance of local interpretation for cultural relevance and acceptance (Cherniakova et al., 2025; Li & Eilks, 2024). The "glocal" approach—translating global goals into locally meaningful actions—emerges as the widely recommended solution (Martín-Sánchez et al., 2022; Yusupova et al., 2025).

Methodologically, the synthesis highlights the need for mixed-method and longitudinal research designs, including validated behavioral indicators, long-term observation, and social metrics to capture collective norm changes (Martínez-Borreguero et al., 2020; Mospan, 2024; Petkou et al., 2025; Tunji-Olayeni et al., 2023). Overall, the thirteen studies demonstrate that education integrating experiential learning, community engagement, and a blend of local and scientific values is most effective in cultivating environmental awareness aligned with the SDGs (Martín-Sánchez et al., 2022; Megawati et al., 2022; Mospan, 2024; Petkou et al., 2025; Yusupova et al., 2025). Eco-school programs and green campus initiatives show that when institutional functions—leadership, curriculum, and community support—are aligned, social norms and ecological habits are more likely to shift (Cherniakova et al., 2025; Megawati et al., 2022; Yusupova et al., 2025).

However, large-scale transformation claims still require long-term evidence, as most studies rely on short-term post-intervention evaluations (Martín-Sánchez et al., 2022; Petkou et al., 2025; Tunji-Olayeni et al., 2023). Educator capacity and policy alignment are operational prerequisites: teachers and lecturers need ESD-oriented PCK, field experience, and institutional support to translate positive attitudes into consistent practice (Álvarez-Nieto et al., 2024; Bezeljak et al., 2020; Martínez-Borreguero et al., 2020; Zinchenko et al., 2024). At the policy level, standardized competency indicators balanced with local flexibility are essential to ensure that ESD initiatives go beyond documentation to tangible implementation (Li & Eilks, 2024; Tunji-Olayeni et al., 2023; Yusupova et al., 2025). Multi-level synergy among schools, universities, governments, industries, and communities is key for education to function as a genuine agent of social transformation toward the SDGs (Cherniakova et al., 2025; Megawati et al., 2022; Petkou et al., 2025; Tunji-Olayeni et al., 2023; Yusupova et al., 2025).

The synthesis highlights three priority recommendations: (a) Position experiential pedagogy (service-, project-, and community-based learning) as the core of ESD curricula with a glocal emphasis (Martín-Sánchez et al., 2022; Mospan, 2024; Petkou et al., 2025; Yusupova et al., 2025); (b) Strengthen educator capacity through action-oriented training and structured practice modules (Álvarez-Nieto et al., 2024; Bezeljak et al., 2020; Martínez-Borreguero et al., 2020; Zinchenko et al., 2024); and (c) Build multi-level policy and evaluation mechanisms incorporating long-term behavioral indicators and adequate resource support to foster collective norm change toward sustainability (Cherniakova et al., 2025; Li & Eilks, 2024; Megawati et al., 2022; Tunji-Olayeni et al., 2023).

3.2 Discussion

This section discusses the main findings from the bibliometric analysis and systematic review, linking them to the research questions and broader literature. The bibliometric

analysis indicates a notable rise in publications on the nexus between education and environmental awareness from 2020 to 2024, peaking in 2024 and slightly declining thereafter. This pattern reflects increasing global concern about sustainability, aligned with the SDG agenda and the incorporation of Education for Sustainable Development (ESD) within national education frameworks (Bui et al., 2024; Leal et al., 2024). The keyword network analysis identified four main research clusters, education and environmental awareness, pedagogy and learning design, policy and human dimensions, and impact and evaluation—illustrating an increasingly integrative and practice-oriented research trend (Fathurohman et al., 2023).

The centrality of "sustainable development" as a keyword confirms that education serves not only as a conceptual foundation but also as a catalyst for social transformation toward pro-environmental behavior. This supports the argument that addressing global environmental change requires concurrent educational reform (Guerrero & Sjöström, 2025; Kioupi & Voulvoulis, 2022). The integration of ESD into STEM education demonstrates that project-based learning, contextualized research, and reflective value-based activities can significantly improve sustainability literacy and problem-solving skills (Martín-Sánchez et al., 2022; Petkou et al., 2025). Nevertheless, sustainability continues to be treated as a peripheral theme rather than as a central pedagogical framework (Mospan, 2024). The primary challenge concerns how to merge local contextual knowledge with scientific literacy to ensure that ESD remains both relevant and evidence-based (Li & Eilks, 2024). As emphasized in recent studies, effective STEM–ESD integration requires connecting technical competence with social empathy and ethical reflection (Alkair et al., 2023).

Educators remain the principal catalysts in implementing ESD. Although many teachers express strong positive attitudes toward sustainability, their efforts are frequently constrained by limited confidence, time, and institutional support (Álvarez-Nieto et al., 2024; Bezeljak et al., 2020). Teachers' self-efficacy increases more substantially when professional development emphasizes experiential and field-based learning rather than purely normative instruction (Boeve-de Pauw et al., 2022). Direct engagement in environmental practice further enhances pedagogical authenticity and confidence (Daumiller et al., 2025). Consequently, teacher education programs should integrate pedagogical content knowledge (PCK) with reflective, action-oriented learning modules (Zinchenko et al., 2024).

Educational institutions and policies constitute the structural backbone of the ESD ecosystem. Programs such as eco-schools and green campuses yield meaningful results when supported by leadership, structural resources, and community participation (Megawati et al., 2022; Cherniakova et al., 2025). However, in many contexts these initiatives remain largely symbolic, lacking systematic follow-up and evaluation (Husin et al., 2025). Although educational programs have significantly improved environmental awareness, a persistent knowledge–action gap remains—the disjunction between understanding sustainability and practicing it consistently (Zhang & Cao, 2025). Empirical evidence suggests that experiential and collaborative pedagogies, such as service learning and community-based projects, are more effective in fostering long-term behavioral commitment (Douglas et al., 2024; Mospan, 2024)

Transformation of sustainability values occurs when cognitive, affective, and social dimensions are intentionally integrated within learning processes (Martínez-Borreguero et al., 2020). Learning that combines emotional reflection with real-world action reinforces intrinsic motivation, empathy, and collective responsibility (Álvarez-Nieto et al., 2024). Therefore, ESD should aim not only to build ecological literacy but also to cultivate sustained moral awareness and ecological empathy (Amprazis & Papadopoulou, 2025). Several limitations should be acknowledged. First, this review analyzed only 13 empirical studies published between 2020 and 2025, which restricts the generalizability of conclusions. Second, the geographic distribution of studies is uneven, with a dominance of European and Asian contexts and minimal representation from Africa and Latin America. Third, most reviewed works employed short-term or descriptive designs, limiting insights into long-term behavioral or policy impacts.

Future studies should expand geographical coverage, adopt longitudinal and comparative designs, and establish measurable indicators to assess behavioral and value transformations over time. In addition, mixed-method approaches are recommended to capture the multidimensional interrelations among education, policy, and ecological action. Overall, the discussion underscores that education has a transformative role in shaping pro-environmental awareness and behavior. Effective ESD implementation requires three synergistic elements: empowered educators, supportive institutional policies, and contextualized, reflective learning experiences. However, the success of sustainability education depends not only on pedagogical innovation but also on the political and institutional courage to make sustainability a core component of the education system, rather than just a moral discourse.

4. Conclusions

In conclusion, this review affirms that education plays a strategic and transformative role in shaping sustainable pro-environmental awareness, attitudes, and behaviors. The analysis of research trends indicates a significant increase in studies exploring the relationship between education and sustainability, with a growing shift in focus from cognitive aspects toward social and policy transformation. Effective implementation of ESD within STEM and science education has been shown to foster scientific literacy and ecological empathy through experiential learning, value reflection, and community collaboration. However, the success of ESD largely depends on educators' competence, self-efficacy, and institutional support, as well as on systemic and adaptive policies at both institutional and governmental levels. Although various initiatives—such as Adiwiyata schools and green campus programs—have demonstrated positive impacts, the persistent gap between knowledge and action remains a central challenge. Therefore, this review concludes that a glocal approach, cross-level policy support, and longitudinal research are essential to continuously evaluate the effectiveness of ESD in shaping sustainable behaviors and values within society.

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Declaration of Generative AI Use

During the preparation of this work, the author(s) used a generative AI tool to assist in paraphrasing certain sections for clarity and Grammarly to assist in improving the grammar and academic tone of the manuscript. After using these tools, the author(s) reviewed and edited the content as needed and took full responsibility for the content of the publication.

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