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Analysis of the Role of Education for Sustainable Development (ESD) in Social, Science, and Environmental Education (2006-2024): Bibliometric Perspective

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Abstract: *The purpose of this study is to determine the trend of education for sustainable development in social science, environmental, mathematics, and chemistry education from a literature review and bibliometric analysis. This paper is also equipped with an explanation of the definition of education for sustainable development (ESD). VOSviewer mapping is used to analyze bibliometric data. The Scopus site is used to obtain research data. The keywords "education for sustainable development", "sustainable development", and "education" are used by us as keyword data searches for this study. We searched for data from 2006 to 2024. The results of the study showed that research on ESD in education was found from 2006 to 2024. In addition, the results of the study also showed that from 2006 to 2013 research increased, but in 2014 it decreased and increased in 2020 and decreased again in 2021. The highest peak of research was in 2022 with 167 articles. This study shows how important bibliometric analysis is to obtain information about the phenomenon. This study is prospective in helping and being a reference for scientists and researchers in conducting and determining research topics, especially regarding ESD.*

Keywords: *Education for Sustainable Awareness, ESD, Social Science, Environmental, Bibliometric Analysis*

INTRODUCTION:

Education for Sustainable Development (ESD) is the latest innovation in education reform, evolving from environmental education.[1], [2], [3]. ESD emphasizes the importance of preparing individuals to face the greatest challenges of the 21st century, with a key role for quality education. In this regard, educators have a responsibility to emphasize the contribution of education to a sustainable future. The emergence of ESD as an international policy discourse has stimulated discussions in various circles, especially in the field of environmental education. However, ESD's primary focus on the "social" aspect distinguishes it from environmental education.[4].

In recent years[5], [6], [7], [8], [9], many studies have shown that interest in Education for Sustainable Development (ESD) is growing rapidly. Along with this development, ESD is increasingly important in a world facing serious environmental problems and increasing social, economic and political disparities. Sustainable development is a real challenge for our society. Problems such as climate change, global warming, natural resource depletion, pollution, high carbon emissions and food shortages demand the creation of a more sustainable society, lifestyle and economy.[10].

According to UNESCO, Education for Sustainable Development (ESD) encompasses a range of disciplines such as climate change, environmental economics, and socio-economic impact management.[11]. Interdisciplinarity is key to understanding the complexity of ESD. ESD is recognized as a holistic approach, integrating sustainability issues into teaching strategies.[12]. In addition, the use of structured and coherent language is very important. As shown by(JB de Pauw et al., 2015), ESD emphasizes participation, collaboration, and engagement, which can change mindsets and promote sustainability competencies such as critical thinking and problem solving.

With strong policy promotion, Education for Sustainable Development (ESD) has seen significant development, and the concept has become a center of discussion in the academic world.Orr (1992)emphasizes that ESD should teach people to think and act sustainably, with a focus on ecological literacy as a primary goal. However,Vare & Scott (2020)argue that ecological principles alone are not enough in developing ESD. They introduce two approaches: ESD1 (learning for elementary school) and ESD2 (learning as elementary school), both of which aim to encourage students to improve their critical thinking skills about the environment.

As a political policy, education should move towards participatory practices, as proposedBarraza et al. (2003).Vare & Scott (2007)emphasizes the importance of both ESD approaches, which complement each other to produce a deeper understanding of sustainability.Huckle (2008)also added a practical dimension to ESD, introducing the concept of active participation and critical pedagogy as an integral part of education. Over time, ESD integrated new educational concepts

that invite everyone to take responsibility for the future of sustainable development, making it a method that can be implemented and followed up in society.

Bibliometrics is an interdisciplinary science in which mathematics, statistical methods and computational techniques are applied in the quantitative analysis of a research field, subject or journal.[19]. The tools used for bibliometric analysis (such as biblioshiny and VOSviewer) have unique advantages in terms of their respective functions. Many academics have achieved outstanding results using these tools in recent years.Wright & Pullen (2007)conducted a bibliometric analysis of ESD publications in the ERIC database for the period 1990–2005. They noted the global nature of ESD publications and the availability of information on communications in the field.Karatzoglou (2013)found that universities have a positive role in integrating elementary education into the curriculum through practices and policies. In addition, he also found that theoretical research on ESD still lacks a conceptual framework, which needs to be addressed in future research. Yu ying zang (2020) in his research also analyzed the historical process and roots of the field of education for sustainable development and to understand the theoretical foundations of the field.

This bibliometric review of research aims to extend previous research reviews by mapping the evolution of social, scientific and environmental education for sustainable development from 2006-2024. Several research questions guide this review.

RQ 1. What is the overall volume, growth trajectory, and distribution of published documents across countries, paper types, and research methods in the knowledge base?

RQ 2. Which journals, authors, and research papers have had the greatest influence on the research?

RQ 3. What are the most frequently studied 'research areas' or topics in recent years in the ESD literature in education?

To answer these four questions, the article is then structured as follows; the "Methodology" section presents the research methodology. The "Results" and "Discussion" sections present the results and discussion respectively. Finally, the "Conclusion" section concludes the paper.

METHODS AND METHODOLOGY:

This literature study uses bibliometric methods to review research on education trends for sustainable development. In this bibliometric review, we analyze various frameworks and techniques that describe the importance of education for sustainable development. In our study, we include research articles published between 2006 and 2024. To gain a deeper understanding of the research topic, we only include journal articles in our study.

2.1 Identification of Sources

Scopus was used as an index to identify documents in this review. Scopus offers extensive coverage across a range of disciplines relevant to ESD, as well as providing access to bibliographic data that can be used by bibliometric software.[22]. Although Web of Science has similar capabilities in exporting metadata for bibliometric analysis, its coverage of educational disciplines is much more limited compared to Scopus.[23].

The types of documents used in the bibliometric review only include open access articles. For the topic focus, the authors chose a set of terms such as “social science”, “environment”, “mathematics” and “chemistry”. This approach narrows the scope of the review, allowing a deeper focus on a particular theme or concept, but it may also miss relevant studies that use different terms but address similar issues. In addition, such specific terms may limit cross-disciplinary exploration or make it difficult to identify studies that cover more than one aspect of sustainable development.

The document sources in this search were left open, without being restricted to specific journals at the outset. Although restricting the search to specific journals is a frequently used strategy[23], [24], the interdisciplinary nature of education for sustainability makes this strategy less practical. Finally, it was decided to limit documents to those published in English, given that Scopus coverage of documents in other languages is still uneven. However, this is one of the limitations of the review that will be discussed further.

The search process used in this review followed the PRISMA guidelines for conducting systematic reviews of research.[25]. We collected data from the Scopus database on September 13, 2024; therefore, citations from papers up to March 23, 2022 were included in the database. The following set of keywords was used to generate the initial database of documents in Scopus.

(TITLE ("education for sustainable development") OR TITLE (esd) OR TITLE ("sustainable development") AND TITLE (education))

This search yielded 3111 documents. Scopus filters were used to filter documents based on broad categories (document type, language, and topic domain), which brought the search results to 822 figure (1).

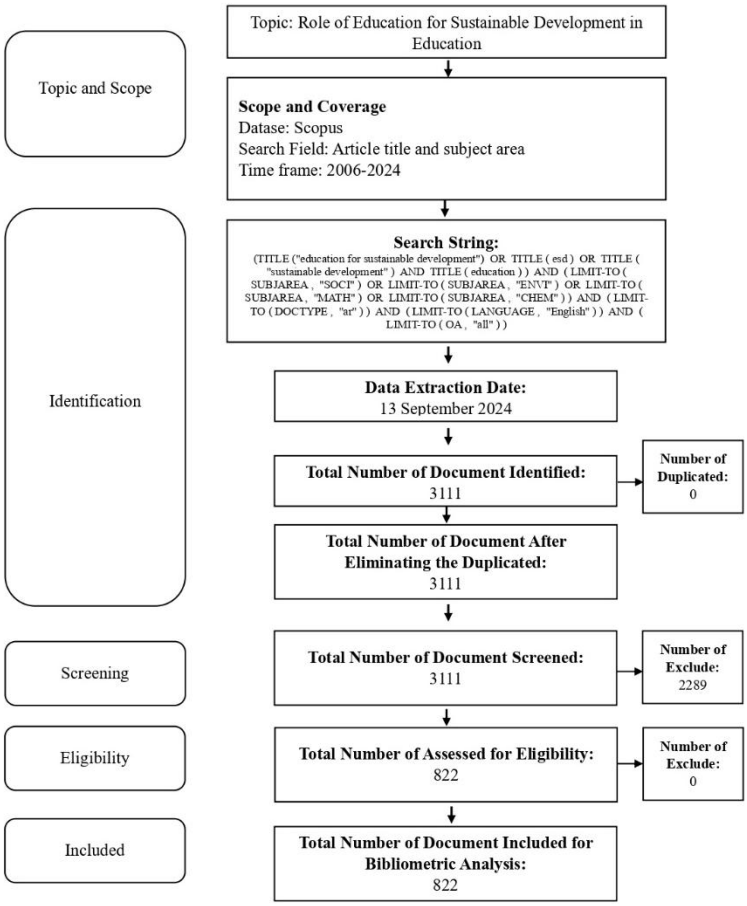

Figure 1 Prism Diagram of this Research

Next, the data obtained from Scopus was then downloaded. The downloaded bibliographic data describes the relevant features of 822 documents to be stored in an Excel file. The file includes 'meta data' related to each article, such as author name, affiliation, article title, source, reference, keywords, abstract, and various citation data. Then cleaning was carried out by creating a thesaurus file. This was done with the aim of uniting author names that were written differently or similar keywords.[26]. The cleaned data was then analyzed using VOSViewer.

2.2 Data Extarction and Analysis

Descriptive analysis is done by analyzing the data statistically. This step includes calculating the number of publications per year, identifying leading authors or journals, and emerging topic trends. Then mapping and visualization are carried out using VOSViewer. VOSViewer is used to visualize relationships between elements, such as co-citation analysis (often cited together), co-authorship (collaboration between authors) or co-occurrence (keyword association). This helps map relationships and patterns in the data being analyzed.

For the final research question, keyword co-occurrence analysis or 'co-word analysis' was used to highlight the topic composition in the HESD knowledge base [22], [26]. This co-word analysis calculates how often two keywords appear together in the title, abstract, or keyword list of documents contained in the review database [van eck]. By performing this analysis, keywords that frequently appear together can be identified, while also showing the relationships between these keywords in a network map [22], [26].

RESULTS

The presentation of results is in line with the three research questions.

3.1 Volume, Growth Trajectory, and Distribution of ESD Literature

Longitudinal analysis of the database shows that the ESD knowledge base has developed in three major stages (see Figure 2).The growth stage emerged from 2006 to 2013, during which 57 documents were published;

The stable growth phase occurred in 2014-2016, where 36 documents were published with a range of 12 documents per year;The accelerated growth stage in 2021 to 2022 is 67 documents within a period of 1 year.

This longitudinal data shows that 74.81% of ESD literature has been produced in the last five years since 2020. This trend confirms that ESD literature is a recent work and attracts rapidly increasing interest among academics.

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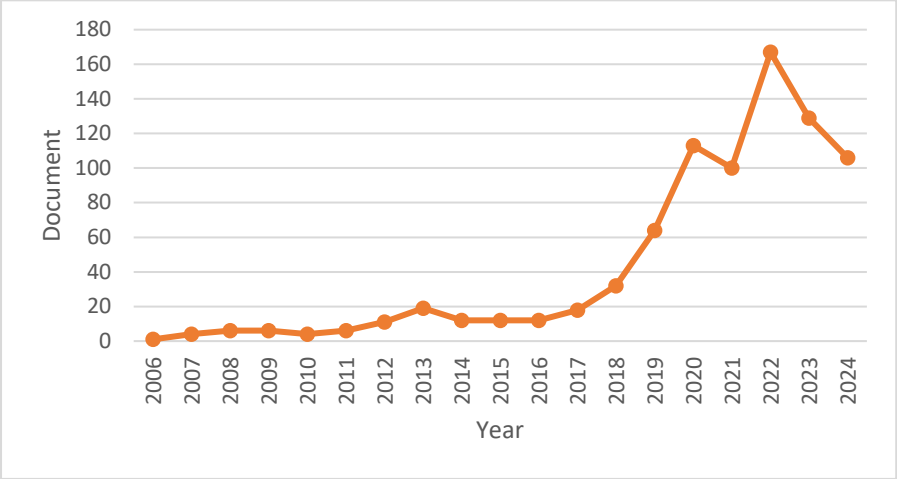

Figure 2 ESD topic research trends from 2006-2024

Contributions to the ESD literature come from academics located in 86 different countries, there is a marked geographical imbalance in this knowledge base (figure 3). The majority of ESD studies are written by academics based in China, Spain, Germany, Sweden and the United Kingdom, which account for 49.8% of the ESD literature (figure 4). However, when broken down by region of publication, 43% of articles were published in developed countries and 57% were published in journals in developing countries. Of this 57% of literature from developing countries, over 80% was published in the last eight years. Further analysis of contributions from developing countries identified that many developing countries have also published in the ESD literature. While this is a positive trend, there are still many blank spots on the map that are developing countries (figure 3). In addition, there are still some developed countries such as Russia and some European regions that have made little contribution to this literature.

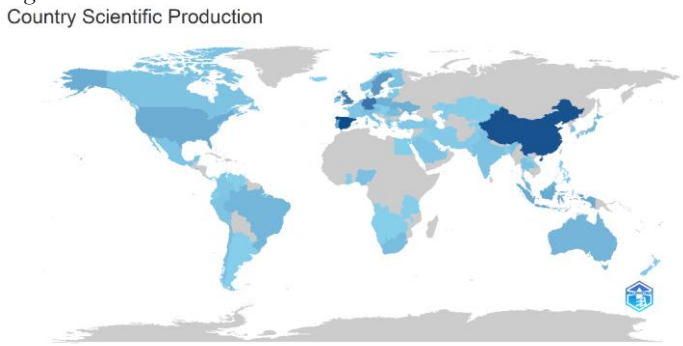

Figure 3 Geographical distribution of ESD research

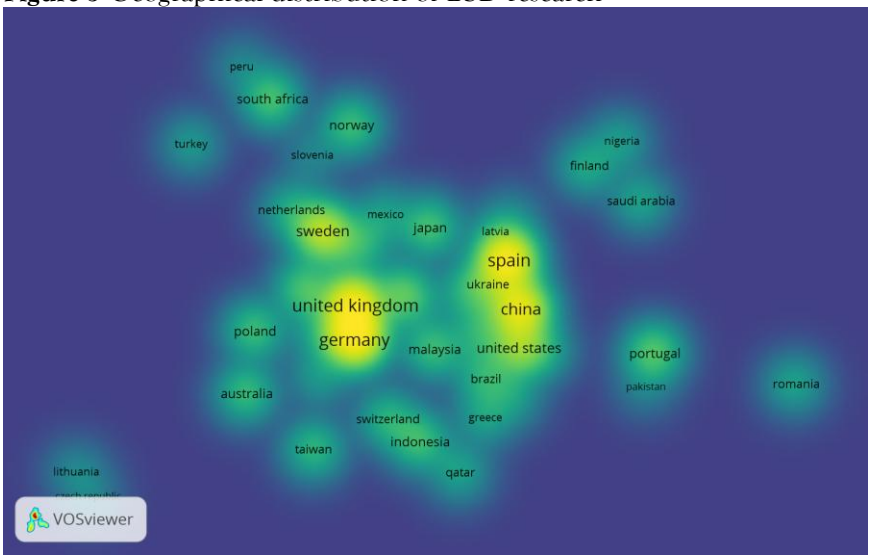

Figure 4 Distribution of ESD topics in several countries

3.2 Influential Journals, Authors, and Documents

Based on the second research question, this section will describe how contributions to the ESD knowledge base are distributed across journals, identifying influential authors and documents. Of the 822 articles obtained in the Scopus database published in 237 different journals. On the positive side, this widespread pattern shows that academic interest

in ESD literature is quite large. In particular, articles discussing ESD have a scope of discussion with general education, environmental education, social sciences, and mathematics. The list of the top 10 journals ranked by the total number of ESD articles published can be seen in table 1.

Table 1. Top journals ranked by total ESD articles published

No	Journal	Document	Scopus cited	H-Index	Subject	Scopus Quartile
1	Sustainability (Switzerland)	296	55991	169	Environmental Science	Q1
2	International Journal of Sustainability in Higher Education	35	2701	77	Education	Q1
3	Environmental Education Research	34	2408	93	Social Sciences	Q1
4	Journal of Teacher Education for Sustainability	34	344	23	Social Sciences	Q2
5	Education Sciences	22	15882	53	Social Sciences	Q2
6	Frontiers in Education	16	7992	40	Social Sciences	Q2
7	Journal of Cleaner Production	15	394597	309	Environmental Science	Q1
8	International Journal of Environmental Research and Public Health	8	339831	198	Environmental Science	Q2
9	Eurasian Journal of Mathematics, Science and Technology Education	7	2354	56	Mathematics	Q2
10	International Review of Education	7	778	46	Education	Q1

Using VOSViewer, it can be identified that the most active and influential journal in publishing ESD content is the journal Sustainability (Switzerland) with 296 articles. Then followed by the International Journal of Sustainability in Higher Education with 35 article documents. These top two journals are our recommendations to be considered as "core journals" in publishing ESD articles. More broadly, the 10 journals in Table 1 publish 57.6% of the total journals in the ESD database. Most of these journals have been indexed by Scopus with concentrations of Q1 and Q2. In this study, Scopus quartiles offer a broad perspective on the quality of journals that will be chosen by readers.

Further citation and co-citation analysis was used to identify the most active and influential academics publishing on ESD topics which can be seen in Tables 2 and 3. This citation analysis highlights the influential contributions of Rieckmann (473), Leal Filho (298), Van Petegem (169), etc.

Table 2. Ranking of active authors writing on ESD topics based on citation analysis

No	Writer	Article	Citation
1	Rieckmann, Marco	8	473
2	Leal Filho, Walter	7	298
3	Peter	7	169
4	Baena Morales, Salvador	7	21
5	Gericke, Niklas	6	424
6	Froberg, Andreas	6	36
7	Leal, Susana	5	193
8	Singer-Brodowski, Mandy	5	82
9	Sprenger, Sandra	5	55
10	Lundvall, Suzanne	5	36

This analysis is also complemented by a joint citation analysis with the authors in table 3.

Table 3. Ranking of active authors writing on ESD topics based on co-citation analysis

No	Writer	Citation	Total Link Strength
1	Rieckmann, Marco	326	11939
2	*Lozano, R	286	12855
3	Leal Filho W	282	11144

4	*Barth M	265	11006
5	Gericke N	225	8203
6	*Sterling s	217	7549
7	*See you soon	215	8954
8	*Walks aej	199	7940
9	*Tilbury d	180	5603
10	*Ceulemans k	154	7716

The results of the author co-citation analysis presented in Table 3 highlight several additional scholars who were not identified through the direct citation analysis. Although this is not uncommon, the author decided to examine the number of direct citations of the scholars marked with an asterisk in Table 3. It was found that all of these highly co-cited scholars are, in fact, among the '50 most cited ESD scholars' as measured by direct citations. Thus, the results of the citation and co-citation analyses largely overlap and reinforce each other. Synthesizing the results from both types of author citation analysis yields a more comprehensive and valid list of influential authors. These include Rieckmann, Leal Filho, Van Petegem, Baena-Morales, Gericke.

Next, a similar series of citation analyses were conducted to identify the most influential documents in the ESD literature. Not surprisingly, many of the most cited documents were written by the academics shown in Tables 2 and 3 (e.g. Rieckmann, Leal Filho, Van Petegem, Baena-Morales, Gericke). The number of Scopus citations achieved by the most cited ESD documents (see Table 4) is in the moderate range when judged by trends reported in other educational literature [23], [24], [27]. This further reinforces the image of ESD as 'a thing in the making'.

Table 4. Most cited ESD documents

No	Article	Scopus citations	Quotes per year
1	[28]Connecting Competences and Pedagogical Approaches for Sustainable Development in Higher Education: A Literature Review and Framework Proposal	404	50.50
2	[29]Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals	314	39.25
3	[30]Education for sustainable development (ESD): the turn away from 'environment' in environmental education?	276	21.23
4	[31]Competencies in Education for Sustainable Development: Exploring the Student Teachers' Views	262	26.20
5	[32]Academic staff development as a catalyst for curriculum change towards education for sustainable development: an output perspective	252	19.38
6	[33]Education for Sustainable Development: A Systemic Framework for Connecting the SDGs to Educational Outcomes	248	41.33
7	[34]The Effectiveness of Education for Sustainable Development	243	24.30
8	[35]The future we want: Key issues on sustainable development in higher education after Rio and the UN decade of education for sustainable development	203	20.30
9	[36]Emerging areas in research on higher education for sustainable development – management education, sustainable consumption and perspectives from Central and Eastern Europe	165	15.00
10	[37]Future sustainability scenarios for universities: moving beyond the United Nations Decade of Education for Sustainable Development	157	17.44

Next, a co-citation analysis of the documents was conducted to gain a broader picture of the documents that contributed to the development of this literature. It is interesting to note that the top 'co-cited documents' were written by[38]not shown in Table 4 of the most cited papers. Further investigation found that the paper fromRieckmann (2017)is not an article but a textbook. This illustrates the capacity of co-citation analysis to identify influential documents without the limitations of the index used by the review.

3.3 Literature Topic Analysis

The final research question concerns the identification of the most frequently studied topics in the ESD literature. This word analysis was used to identify the main topical focus in the ESD database.[26]. The difference between co-word analysis and citation analysis is that co-word analysis examines the keywords of a document as a means of synthesizing trends. This analysis uses VOSviewer. Vosviewer produces a temporal co-word map that can be used to reveal how frequently and recently keywords appear, the occurrence of these keywords is expressed through different colors. VOSviewer will identify

the occurrence of topics in a document over time and assign lighter colors to topics whose distribution is concentrated in the last few years. Keywords identified through word analysis represent the beginning of growth[39]from ESD literature.

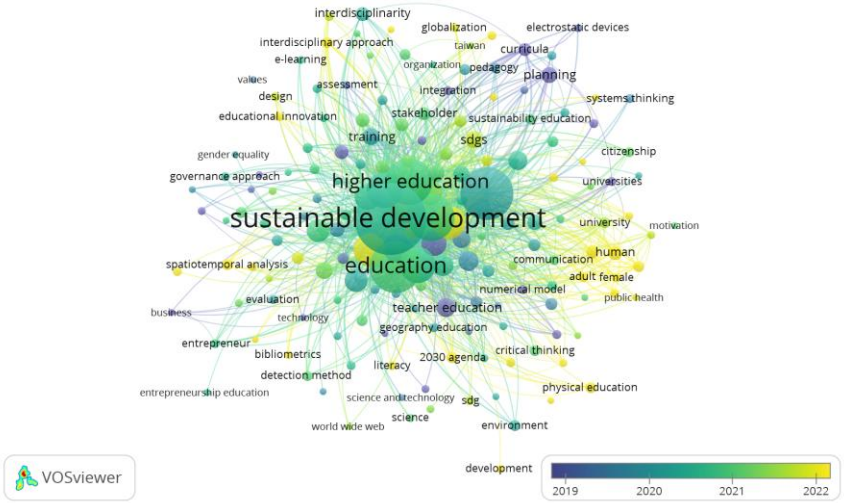

Figure 5 Distribution of frequently used keywords

The first analysis examines the frequency of topics appearing in the ESD literature. Ignoring the search keywords used (sustainable development, ESD, environmental education, mathematics, chemistry, and social science), the topics that emerge from this analysis are sustainable development (427), education (223), sustainability (179), higher education (186), learning (109), teaching (106), and curriculum (64).

The approach used to identify current 'research areas' or topics of greatest interest involves the synthesis of themes from related keywords in the ESD knowledge base [22], [26]. First, the topics with the lightest colored nodes were grouped into general themes, and then sorted by the sum of the combined topic frequencies. Four main themes were identified in this ESD research area: Sustainable development; Education for Sustainable Development; Interdisciplinarity and Higher Education; and Competencies and Critical Thinking.

The first theme, Sustainable development, focuses on sustainable development goals and how to achieve them through education. This theme includes several keywords including: Sustainable development, SDGs, environmental education, climate change, decision making. This theme is directly related to environmental education where teaching focuses on climate change awareness, resource management and sustainability. This is an integral part of the SDGs, which is a framework for environmental education to encourage real action.The second theme, Education for Sustainable Development (ESD), focuses on how education contributes to sustainable development by covering various aspects of curriculum and training. This theme includes keywords with focus such as curriculum, teacher training, quality education, university sector, strategic approach. Quality education in ESD includes laboratory training that supports the understanding of environmentally friendly chemical processes, such as the use of renewable materials or chemical reactions that do not produce hazardous waste. This can be included in the chemistry curriculum at the secondary school or university level. While in social sciences, strategic approaches and sustainability education policies at the university or national level are often analyzed. Social sciences help students understand the social impacts of environmental policies, as well as how sustainability issues relate to governments and institutions.The third theme, Interdisciplinarity and Higher Education, highlights the importance of interdisciplinary approaches in higher education to promote the integration of sustainability into various fields of study. This theme includes the following keywords: Interdisciplinarity, higher education for sustainable development, engineering education, knowledge innovation. Knowledge innovation can be used to create algorithms or mathematical models that predict the long-term impacts of environmental policies.The fourth theme refers to Competencies and Critical Thinking, this theme focuses more on developing individual abilities needed to face sustainability challenges, such as critical thinking skills and complex decision-making. In environmental education, students are trained to make decisions based on data and sustainability principles. Mathematics is used to hone analytical skills through modeling environmental problems, while in chemistry, students are invited to think critically about environmentally friendly chemical processes. In social sciences, communication and leadership competencies play an important role in influencing policies and community behavior towards sustainability, integrating social, economic, and political understanding.

DISCUSSION

The bibliometric review in this study attempts to map the knowledge base on Education for sustainable development through a bibliometric analysis of 822 Scopus indexed documents published between 2006-2024. The mapping focuses

on illuminating ESD trends in knowledge production rather than a synthesis of research findings. As such, this review does not replace the need for a research review examining the results of studies in the knowledge base. The use of Scopus indexing allows for the identification of a large number of documents, for example it is noted that the scope of this review is limited by the type of source and the index from which the documents were extracted. However, the impact of this limitation is somewhat mitigated by the use of co-citation analysis, which allows the identification of 'co-cited' documents located in the wider literature that are omitted from Scopus.[27].The journal analysis that has been conducted can be concluded that ESD literature is published in a group of good quality journals that are widely distributed and cross-disciplinary. These journals specialize in the fields of environmental education, mathematics, and social science. The results of the journal analysis are generally consistent with those reported by Phlip (2019). More specifically, it was found that the journal that most frequently received articles related to ESD was the journal Sustainability (Switzerland) (ranked 3 by [27]), International Journal of Sustainability in Higher Education (ranked 1 by [27]), and Environmental Education Research (ranked 4th by[27]). The consistency of the results between the two reviews is more significant than the small differences in journal rankings. Furthermore, this could be attributed to the different lengths and focuses of the reviews. In contrast, Philip and colleagues, this review extends the analysis of ESD journal publications to include an analysis of scientific impact. Using direct citation analysis, they found that the journal rankings by citation impact mirrored the rankings by volume (see Table 1). Thus, SS, IJSHE and EER are 'core journals' publishing research on ESD. Furthermore, as mentioned earlier, these journals are all high-quality journals,According to White & McCain [40] states that in bibliometric analysis, the greatest strength is the capacity to identify primary authors and texts through empirical analysis of the literature. The citation and co-citation analysis in this review documents the scholars who have made significant contributions to date.Finally, co-word analysis is used to explore 'research fronts'. White & McCain [40] in the topic of ESD. Analysis of frequently occurring keywords yielded a series of complementary themes indicating current topics of interest to academics. These included Sustainable development; Education for Sustainable Development; Interdisciplinarity and Higher Education; and Competencies and Critical Thinking. The findings on these 'hot topics' again differed from those reported [27], which uses contrast methodology on overlapping but distinctly different data sets.
This study provides several implications, including in strengthening the quality of education. Bibliometric analysis of the role of ESD shows that the integration of sustainability principles in education has a significant impact on improving the quality of education as a whole. Educational institutions that implement ESD tend to produce students who are more critical and ready to face global challenges. In addition, the results of the analysis also indicate that the ESD approach encourages the involvement of various disciplines in solving sustainability problems, from economics, social sciences, to technology. This has positive implications for increasingly integrated cross-disciplinary collaboration.
Some other implications are in terms of curriculum change and increasing social awareness based on bibliometric studies, it is increasingly clear that there is a need to revise the education curriculum to include more content on sustainability. Curriculums that support ESD can help learners better understand their role in protecting the environment and society globally. Education that focuses on sustainable development not only increases students' awareness of environmental issues, but also promotes a higher social awareness of justice, equality, and collective responsibility. In addition, one of the important implications of ESD integration is a direct contribution to the achievement of the Sustainable Development Goals (SDGs) by the UN, especially goal number 4 on quality education and number 13 on action on climate change.
However, there are also some obstacles in this study. One of the main obstacles in implementing ESD is limited resources, both in terms of teaching staff, infrastructure, and learning materials. Many schools and universities, especially in developing countries, face challenges in obtaining sufficient financial and technical support to adopt ESD. Another significant obstacle is the differences in social and cultural contexts between countries or even between regions within a country. Some regions may not have the same concerns about sustainability issues, which makes ESD adoption more challenging.
Finally, beyond specific findings, this review reinforces the growing recognition that education will play a key role in global efforts to achieve the UN Sustainable Development Goals. This is evident in the growth trajectory of the ESD literature, its cross-disciplinary composition, the breadth of journals featuring ESD content, and the quality of journals and scholars who have engaged with the topic. Taken together, these trends converge to paint a picture of a burgeoning interdisciplinary field of study with the potential to influence policy and practice in the years to come.

CONCLUSION

Education for Sustainable Development (ESD) has emerged as a major innovation in educational reform, with the aim of preparing individuals to face the challenges of the 21st century. This study examines the development of ESD-related literature from 2006 to 2024 using bibliometric methods. The results of the analysis show a significant increase in the volume of publications related to ESD, which are largely influenced by global environmental, social, economic, and political issues. The literature on ESD in various journals and by authors from many countries shows a broad interest in this topic, especially in the fields of environmental education, social sciences, and science. In this literature, the main

themes that are widely discussed are sustainable development, education for sustainable development, interdisciplinary approaches in higher education, and critical thinking competencies. These themes illustrate the great academic attention to the importance of education that emphasizes sustainable development as a solution to global problems. ESD also has a positive impact on improving the quality of education, producing graduates who are more critical and ready to face global challenges. However, there are obstacles in the implementation of ESD, especially in terms of limited resources and differences in socio-cultural contexts. These findings emphasize the importance of ESD in achieving the UN Sustainable Development Goals (SDGs), particularly in quality education and climate action.

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