Profitable Consideration of Education for Sustainability Development (ESD) above a Time: Bibliometric Analysis

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Abstract

The objective of this study is to provide a concise overview of research on education for sustainable development, focusing on scientific production, prominent researchers, nations involved, and research topics. An analysis of the scholarly output on the topic of education for sustainability development was conducted using bibliometric methods, focusing on publications published from 2013 to 2023. A total of 19,801 articles were retrieved from Scopus databases. Collecting data was finished, and the data was stored in two specific file formats, namely *.ris and *.csv. The *.ris format serves as the data mapping format in the R Studio and VOSviewer applications, while the *.csv format is utilized for data analysis in Ms. Excel. These papers were published in various publications related to sustainability, social sciences, engineering, and scientific education. The primary findings indicate that the quantity of articles about education for sustainability development is reasonably consistent from 2013 to 2023. Co-authorship relationships primarily involve researchers from the same nation. Furthermore, a change in the research priorities was noted. Prior research has been extensively conducted in various fields, including sustainability, social sciences, engineering, science education, and others. A recent study has highlighted the significance of curriculum and curriculum development. The research implication is bibliometric analysis, which can help identify research trends related to education for sustainability (ESD). This may include the latest research, topic focus, and recent developments in the field.
Keywords: bibliometrics; education for sustainability development; engineering; sustainability

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INTRODUCTION

The concept of sustainable development was initially introduced in the United Nations (UN) World Environment and Development (WECD) commission report. In 1987, during the United Nations general assembly, sustainable development was defined as a guiding principle for structuring human progress to fulfill the long-term requirements of existence. The effectiveness of integrating ESD into school curriculum and practice is heavily contingent upon the proficiency and dedication of

teachers regarding sustainability. The notion of sustainable development encompasses both economic and social development advantages (Alm & Bailey, 2021). Additionally, it places significant emphasis on environmental concerns (Abd-Mutalib et al., 2023). The United Nations declared the Sustainable Development Goals (SDGs) through the general assembly in Rio de Janeiro on December 25, 2015. These goals were adopted from the 2030 agenda (Campbell et al., 2022). The Global Program of Action (GAP) aims to build upon the progress made during the United Nations Decade and ensure widespread access to knowledge, skills, values, and attitudes that empower individuals. This objective has been in place since 2015. "To foster sustainable development" (Mochizuki, 2019).

The 2030 Agenda outlines 17 sustainable development objectives. The 17 SDGs possess transformative, inclusive, and universal attributes that delineate the obstacles to sustainable development, aiming for prosperity, peace, justice, and a habitable planet for all individuals (Olmos Antillón et al., 2021). ESD serves as a means to accomplish the SDGs objectives. It has the potential to facilitate the societal changes necessary for achieving a sustainable nation (Agirreazkuenaga, 2019). ESD is a comprehensive concept that examines development from social,

economic, and environmental perspectives. The implementation of ESD in Indonesian education, particularly in science instruction, has been limited. Hence, the objective of this study is to provide a concise overview of research on education for sustainable development, focusing on scientific output, prominent researchers, nations involved, and research areas. The benefit of this research is to provide a brief overview of education for sustainable development, focusing on scientific production, leading researchers, countries involved, and research topics (Martin & Bartolome, 2023). Bibliometric research using RStudio can make a significant contribution in helping to identify research trends related to education for sustainability. This includes identifying the main topics being studied, shifts in trends over time, and the research foci that have received the most attention from the academic community (Kulevicz et al., 2020). The difference between this research and previous research is in the tools used. We use Rstudio, which is still rarely used in bibliometric research. Furthermore, the bibliometric R package was employed for the bibliometric study, whereas VOSviewer was utilized to visually represent the science mapping outcomes. Table 1 presents a comprehensive overview of the data and software analysis tools.

Table 1 Summary of data analysis and software analysis tool

Research Question	Main Method (Actual Analysis)	Science Mapping Tool
Which keywords were most significant, and what co-occurrence patterns exist in research on education for sustainable development between 2013 and 2023?	Science mapping (co-word analysis)	R package bibliometrix ver. 3.3.0
Which authors and nations had the greatest impact on publications regarding education for sustainable development between 2013 and 2023?	Performance analysis involves identifying the most productive authors based on their scientific publications over time and determining the most productive countries.	R package bibliometric ver. 3.3.0

Research Question	Main Method (Actual Analysis)	Science Mapping Tool
Has there been substantial evidence of widespread collaboration among academics and nations in education for sustainability research between 2013 and 2023?	Scientific mapping, also known as co-authorship analysis, is a method used to analyze and visualize the collaborative relationships between authors in scientific research.	R package bibliometrix ver. 3.3.0

METHOD

The rapid progress of information technology in the twenty-first century has resulted in significant improvements in data collection, organization, manipulation, and interpretation (Chiang et al., 2020). Consequently, there has been a surge in the use of bibliometric analysis in scientific research on education in recent years. Various topics, including technology and higher education (Ahmed et al., 2023), engineering design (Chiang et al., 2020), scientific literacy (Alan et al., 2023), project-based learning (Barak & Assal, 2018), STE(A)M (Anabousy & Daher, 2022), and the connections between authors in the field of science education research (Abdullah et al., 2014), are being analyzed using bibliometric methods. The analysis is utilized because it aids in identifying and mapping collective scientific research subjects and provides a thorough account of scientific outcomes and their progress in the examined field of study throughout time (Nugraha et al., 2023). The research focuses on the keyword "Education for Sustainability Education (ESD)."

Keywords are utilized to designate articles that are deemed pertinent. The abstract and title are criteria for picking articles based on pre-established keywords. The study period included in the evaluation process spanned from 2013 to 2023. On January 11, 2024, a data search was performed using the R Studio application, which resulted in discovering 19.801 articles that Scopus indexed. Scopus is an open-source article search platform that indexes article data. It allows users to access articles and citations from diverse sources without any restrictions based on the reputation of the article or its publisher. Once the process of collecting data is finished, the data is stored in two specific file formats, namely *.ris and *.csv. The *.ris format serves as the data mapping format in the R Studio application, while the *.csv format is utilized for data analysis in Ms. Excel. Microsoft Excel is utilized annually to examine development data and arrange articles according to their highest citation count. The study concept and methodology of this paper are illustrated in Figure 1. The methodology employed is elucidated in Figure 1.

Phase 1 Study Design: Formulate the research questions and define the specific date of data collection for the study

Phase 2 Data Collection: Select the appropriate database; Construct a set of criteria for the search query; and Filter and export data into a document

Phase 3 Data Analysis: Select the proper method to answer the research questions; Select the appropriate bibliometric software; and clean the data

Phase 4 Data Visualization: Select the appropriate mapping software to conduct the visualization; Choose the corresponding visualization method

Phase 5: Interpretation, explain and discuss the output of the software
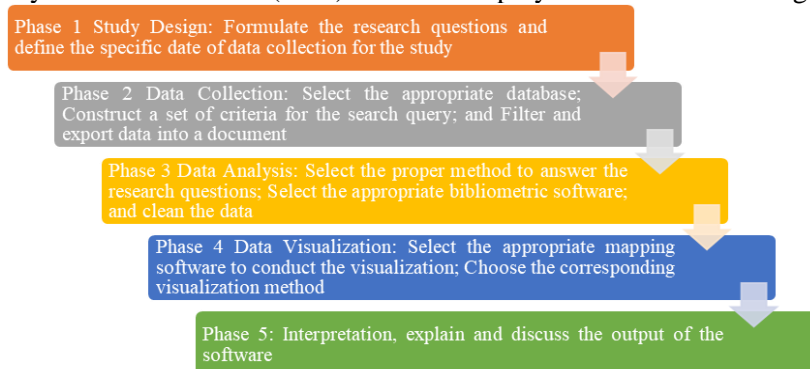
Figure 1 Science mapping workflow using bibliometric analysis

The study utilized the conventional science mapping procedure, as Assefa and Rorissa outlined in 2013. This adaptation is visually represented in Figure 1. The subsequent section presents the sequential steps of Phase 1-4, while the outcomes section discusses the research findings. The final portion presents an analysis and discourse on the findings. Table 2 concisely summarizes the data utilized for the bibliometric analysis.

Table 2 Summary of data extraction from scopus and data used in bibliometric analysis

Output	Result
Main Information About Data	
Timespan	2013:2023
Sources (Journals, Books, etc)	5642
Documents	19801
Annual Growth Rate %	13.16
Document Average Age	3.82
Average citations per doc	9.241
References	1
Authors	
Authors	54148
Authors of single-authored docs	2812
Authors Collaboration	
Single-authored docs	3400
Co-Authors per Doc	3.84
International co-authorships %	13.98

RESULT AND DISCUSSION
Keyword co-occurrence patterns in education for sustainability development research

The word cloud method was employed to ascertain the most commonly utilized terms. Word clouds, a data mining technique, visually display the most frequently used terms in a given text or phrase (Shu et al., 2021). It is widely recognized that the word located in the middle represents the most frequently used word about that particular subject area. As the word size diminishes and shifts out from the center, it signifies that the term is employed with lower frequency. The results of our analysis indicate that the terms with the highest frequency of use include sustainable development (f = 2705), education (f = 2119), sustainability (f = 1991), human (f = 1511), and others. Previous research on co-word annotation, especially using analysis tools like RStudio, has provided valuable insights into the relationships between keywords in the analyzed texts.

This technique is usually used in text analysis and bibliometrics to identify patterns and relationships between words that appear in a text corpus (Karaca et al., 2023).

In previous research, co-word analysis has often been used to understand text corpora's conceptual or thematic structure, including in fields such as social sciences, information sciences, and humanities studies. In the context of co-word explanations, words that appear together repeatedly in the text are considered to have a close relationship or are interrelated (Kurtuluş & Tatar, 2021).

In co-word analysis, the words that appear most often or have the highest frequency of use represent the most dominant concepts or topics in the text corpus. For example, in your analysis results, the words "sustainable development", "education", and "sustainability" have a high frequency of use, indicating that these topics are the main focus of the analyzed texts. The

following explanation is shown in Figure 2.

Figure 2 Top 10 Word Cloud ESD

The results of the co-word analysis were visualized using the Rstudio program. A similarity matrix was computed based on a normalized co-occurrence matrix, and the software produced a two-dimensional map. In order to acquire comprehensive data, terms extracted from the titles of the articles, the abstracts, and the author keywords have been incorporated in the co-words analysis. Co-word analysis involves modeling word relationships in a document or text corpus. The results of co-word analysis usually include a co-occurrence matrix between words that shows how often the words appear together in the text. In addition, word network visualizations or clustering of words based on co-occurrence are often produced. Meanwhile, co-occurrence analysis is broader and can involve relationships between entities or elements other than words, although, in this context, we will still focus on words. The result of co-occurrence analysis can be a co-occurrence matrix between words that shows how often two words appear together in the text. Word network visualizations or clustering of words can also be generated. Co-word and co-occurrence analyses are concerned with understanding the relationships between words in a document or text corpus (Kulevicz et al., 2020). Both try to identify words that frequently appear together and explore the relationships between the concepts presented by these words. In addition, there is a correlation between the results of the two analyses. The co-occurrence matrix resulting from co-occurrence analysis can be used in co-occurrence analysis in general, while the co-occurrence matrix resulting from co-occurrence analysis can be used in the co-word analysis. In other words, they can complement each other and provide deeper insight into the structure and relationships in the text. The complete co-word network is visualized in Figure. 3.

Figure 3 Final visualization of co-word analysis

Figure 3 The font size corresponds to the relative frequency of term occurrence, while the connecting lines indicate keyword co-occurrence. Term clusters that exhibit frequent recurrence are emphasized with a consistent color. The co-word analysis uncovers multiple clusters that are not mutually exclusive. The red and blue clusters are the two primary entities that influence the mapping most. The largest cluster, known as the red cluster, has eleven phrases, including "sustainable development," "education," "sustainability," and others. Research on education for sustainable development involves the examination of various interconnected keywords and co-words. However, it is challenging to identify specific clusters. "human" typically denotes the singular form, specifically a particular human being. Within bibliometric data, the keyword "human" indicates a study or literature that primarily focuses on human persons' attributes, actions, or occurrences. Meanwhile, the term "Humans" denotes a plural form, specifically indicating several individuals of the human species. In bibliometric analysis, the keyword "humans" indicates that the research or literature pertains to human populations, perhaps emphasizing various characteristics such as populations, societies, or specific groups of humans within a given context. Utilizing suitable keywords in bibliometric analysis facilitates the filtration and acquisition of more precise information based on the research or analysis's unique requirements. Sustainability development commonly emphasizes education, with research in social sciences, engineering, and instructional science playing a significant role. As a result, academics have incorporated multiple elements while studying education for sustainable development (Imara & Altinay, 2021). The opening part emphasizes the extensive research efforts on education for sustainability development that have been conducted during the 2010s. Various research fields have significantly contributed to understanding the essence of education for sustainable development, and scholars have used multiple instructional methods to facilitate students' education in this area. The co-words analysis results reveal multiple clusters encompassing diverse research focus aspects.

Collaborations among Researchers and Countries in ESD Research

The involvement of multiple researchers in collaborative efforts has substantially impacted the output of scientific work (Adler et al., 2016), the achievement of high academic standards (Abdeen, 2020), and the progress in constructing knowledge in contemporary science. It enables the transmission of knowledge and expertise while decreasing mistakes' duration and occurrences (Nugraha et al., 2023). Not all forms of research collaboration are formally documented in academic publications (Chen et al., 2022). Nevertheless, the number of collaborative publications can indicate academic collaboration among scholars (De Grandi et al., 2021) owing to their positive association.
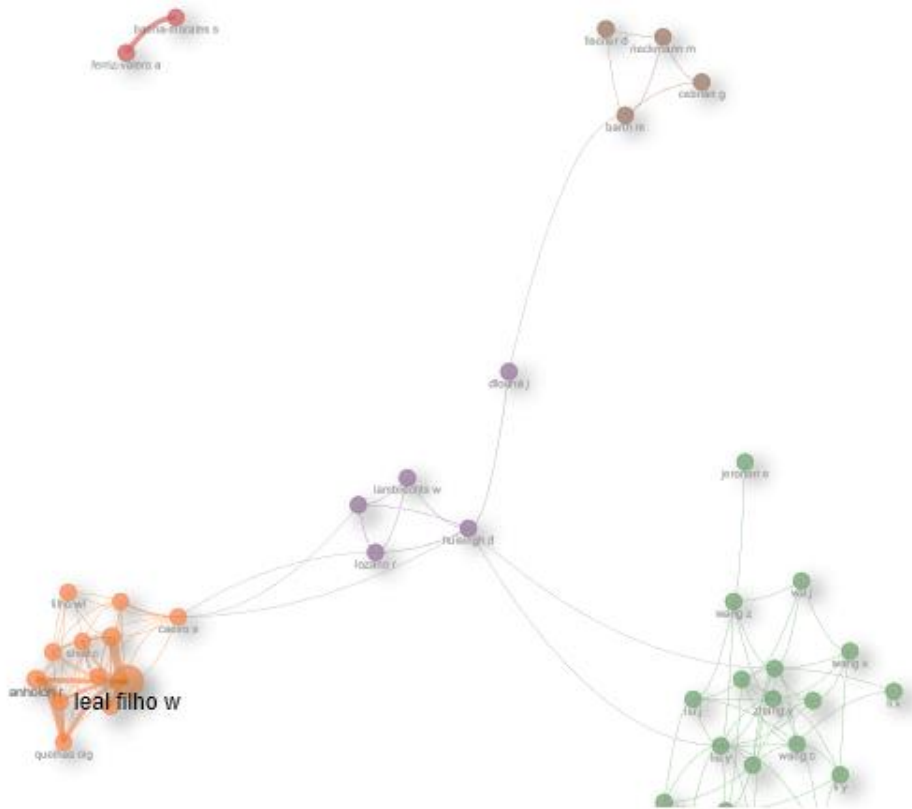
Figure 4 Co-authorship network concentrating on authors of education for sustainability development research publication from 2013 to 2023

Therefore, a co-authorship analysis was performed to evaluate the extent of collaboration among researchers in the ESD research community, and the results are displayed in Figure 4. Each node depicted in Figure 4 represents a distinct author, and the node's size is directly proportional to the number of articles authored by that writer. The lines connecting two nodes represent publications that the corresponding authors have collaboratively authored. The line's thickness directly correlates with the quantity of co-authored articles. The colors correspond to the distinct clusters. The research is limited to authors with at least two collaborative works that meet the clustering requirements. To elucidate, the graphic excludes authors who have published works authored solely by themselves.

From Figure 4, it is evident that multiple distinct clusters comprise a small number of authors. Three collaborations between two authors exist, indicating that cooperation has occurred among ESD researchers. However, no authors in one cluster have engaged in considerable collaboration with authors from different clusters.

Prominent Scholars and Nations in Publishing Articles on Education for Sustainable Development Investigation

A further examination was undertaken of the most prolific scholars in the field of Education for sustainable development, focusing on the number of articles published and citations received between 2013 and 2023. Although certain highly active authors have consistently made contributions to the field through publications in the past decade, it is evident that others have concentrated their publishing efforts within a shorter

timeframe, particularly starting in 2019, as depicted in Figure 5. However, Baena-Morales et al., (2021), the corresponding

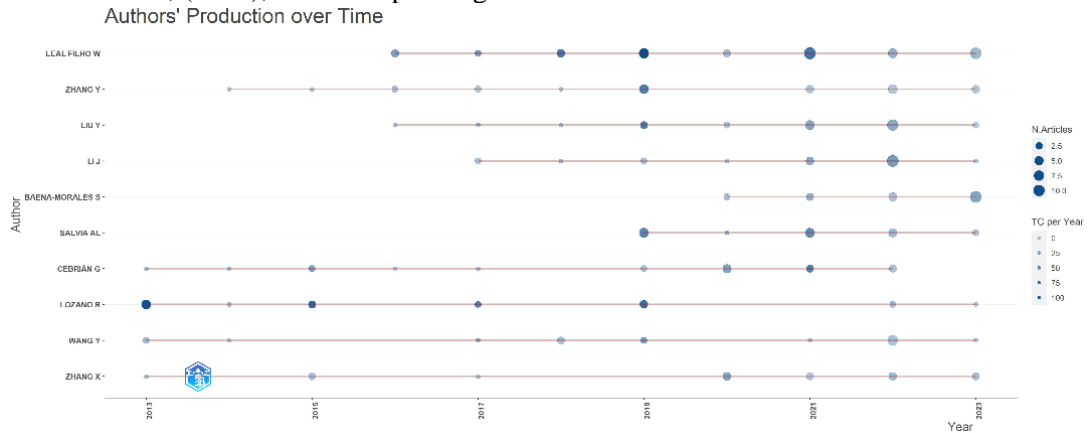author, have not released any works since 2019.

Figure 5 Top authors' production over the time

Given that the total number of citations in Figure 6 includes citations from sources outside the field of education for sustainability development research, it is important to determine the most important articles for the education for sustainability development research community. This can be done by analyzing how many times other authors have cited a particular article in the

dataset within the same collection, referred to as the number of local citations. An analysis was also performed on the nations of the relevant authors' publications to provide a synopsis of the countries contributing to the scientific discourse on research related to education for sustainable development. The analytical findings are displayed in Figure 6.
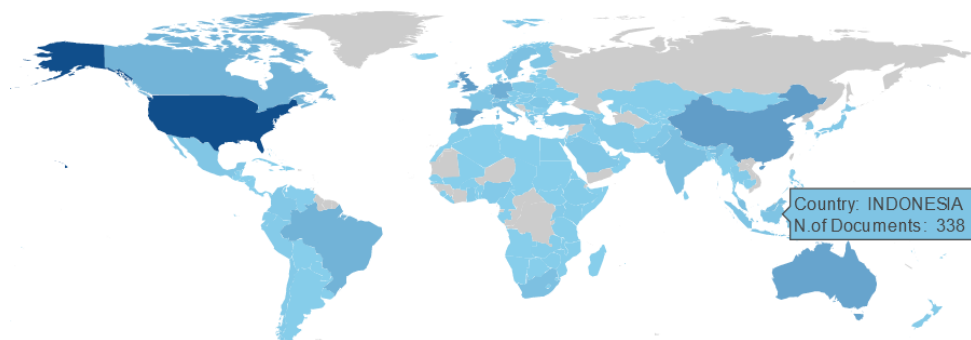

Figure 6 Corresponding author's country

Figure 6 shows that the top ten publishers are comprised of countries from the USA, Asia, Australia, and Europe. Numerous writers from diverse regions have mostly researched Education for sustainable development. Specifically, the USA contributed the largest number of publications on education for sustainability development, with 1498 articles accounting for about

one-fifth of the analyzed publications. In addition, the proportion of publications involving multiple countries was only 6.1%. China has the highest proportion of publications involving numerous countries, accounting for 21.8%. The United Kingdom follows with 25.6%, Germany with 13.6%, and Indonesia with 14.2%. These findings demonstrate the limited scope of stem education research

in Indonesia and emphasize the need for further development (Maryanti et al., 2021). The gap in this research is in the proportion of multinational publications; although most publications come from the United States, the proportion of publications involving many countries is only 6.5%. This shows that cross-border collaboration is still relatively low in the context of Education for Sustainability (ESD) research (Yuliani & Hartanto, 2020). Cross-border collaboration can bring benefits in developing broader thinking, exchanging ideas, and utilizing diverse expertise. Apart from that, there is a need for further development in Indonesia because these findings highlight the importance of further development in Education for Sustainability (ESD) research in Indonesia. With the proportion of publications involving many countries still low, there is an opportunity to increase international collaboration in Education for Sustainability (ESD) research in Indonesia (Satrianawati & Fu, 2019). This can be done by building collaborative networks with researchers and institutions from other countries and increasing investment in research and development of higher education.

CONCLUSION

Ultimately, the findings of this study have the potential to advance the field of Education for sustainability development and inspire scholars to explore new research areas and collaborate internationally. This work is motivated by the extensive literature on Education for sustainability development. It aims to present a comprehensive overview of the current scientific literature on this subject and the transition to its emerging condition. So this research can provide a brief overview of Education for sustainable development, focusing on scientific production, leading researchers, countries involved, and research topics.

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