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Review Article

Sustainability in Science Education: A Bibliometric Analysis during 2000–2022

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Abstract
Sustainable has a better concept of human life amid natural limitations by always maintaining a balance of life in the social, economic, and environmental fields. One of the efforts that can be made in realizing the SDGs is through education. The concept of science and science education is considered a determining factor for achieving the SDGs. Several studies have explored the relationship between science learning in sustainability and its impact on the environment and learning outcomes. However, bibliometric studies that study in this field are still very rare, previous bibliometric studies have analyzed a lot about sustainability in the field of education both at the primary, secondary, and tertiary levels. The purpose of this study is to provide a bibliometric analysis of sustainability in science studies by analyzing documents published by Scopus. A sample of 797 documents through 2022 was analyzed. The data is processed and the results are graphically illustrated using VOSviewer software. The study analyzes the emergence of publications by year in the period 2000-2022, keyword trends, most cited references, most prolific sources, institutions, countries, and authors. In addition, the co-authorship status for the author, the country, and the distribution of author keywords are also analyzed and depicted in the form of a network visualization map in the form of lines and nodes. This research provides insights and future research opportunities on sustainability in science education.

Keywords: Bibliometric analysis, Science education, Scopus, Sustainability, VOSviewer

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1. INTRODUCTION

Sustainable development is a development that can meet the needs of humans today without reducing the capacity or ability of the next generation to meet their needs later. In line with this, the term sustainable has the concept that humans have a better life amid existing natural limitations by always maintaining the balance of life in three dimensions, namely social, economic, and environmental. In sustainable development, there are 17 global goals with a total of 169 measurable achievements called sustainable development goals (SDGs) (UNESCO, 2017). The United Nations (UN) said that one of the efforts that can be made in realizing the SDGs is through education. Education is expected to help design a better sustainable future and aid efforts to address environmental crises. This approach through education is known as Education for Sustainable Development (ESD) (UNCED, 1998).

ESD will equip students with a variety of competencies, namely competencies of knowledge, skills, values, and attitudes so that students in the future can take actions that are responsible for the environment, economic sustainability, and just society. ESD integrates learning objectives, learning content, pedagogy, and learning environment, as well as social transformation into a quality education system that supports the creation of sustainable development goals (Ledoux, 2002). It can take the form of developing the appropriate learning methodologies, resources, and educational policies to accomplish sustainable goals; assessing the difficulties encountered with those used in the classroom; figuring out what influences students' sustainability awareness; investigating new learning environments and methodologies (such as Massive Open Online Courses, flipped classrooms, or serious games in sustainability); and rethinking the curriculum to prepare students for the future (Grosseck, 2019).

Murphy (2018), states that the concept of Science and science education is considered a determining factor for a sustainable world, where both things relate to and contain safe food and water supplies, good health is guaranteed, and our climate and biodiversity are well maintained. It has been claimed that ESD in relation to science education may be able to contribute to all three pertinent areas of science instruction (personal, social, and vocational relevance) (Eilks and Hofstein 2014). However, the current state of science education on the concept of sustainability has not yet developed so transformative empowerment and pedagogy are needed that encourage interest and continuous participation in students, and science learning is also expected as a collaborative process to imagine and enact a sustainable future starting at this time. In short, there is a need for a rapid social transformation towards sustainability in a way that substantively engages learners in learning as well as the need to redefine science in Education not as a "competitive advantage" but to protect the environment from future threats. In addition, given the extraordinary nature of sustainability challenges, there is a need to encourage learners' actions on sustainability topics in a way that promotes their interest and engagement on an ongoing basis (Carlie D. Trott; Andrea E. Weinberg., 2020)

The involvement of science education in the influence of sustainability has a very important factors to achieve sustainability goals and address problems that arise in their application. Therefore, a study or analysis is needed, one of which is in the form of bibliometric research on the topic of sustainability in science education. Although bibliometric analysis is not a tool that can be applied to all fields, (Grosseck, et al. 2019) say that the entire scientific community uses bibliometric analysis as a tool for managing their data. This is done with various purposes such as to assess the quality of a study; evaluate the quality of the journal; classify types of scientific networks and map scientific cooperation, at the interagency, national, and international levels; as well as organizing hierarchies, by comparing one country to another, or one institution in relation to a country. While visualization in the bibliometric analysis is usually assisted by software. There are many software programs used to analyze and visualize bibliometric networks, each of which has an advantage in one or another specific function. CiteSpace, CiteNetExplorer, VosViewer, Publish or Perish, Pajek, and Gephi.

1.1 Aim of the Study

Previous bibliometric research has been widely presented related to sustainable development in the field of Education both Education in general ((Côrtes and Rodrigues (2016); Grosseck et al, (2019); Hallinger and Vien-Thong, 2020) and college (Hallinger and Chatchai (2019); Machado and Davim (2022); Ghani, et al

(2022). The importance of current research is that, as far as the authors know, there have been no bibliometric studies of sustainable development in science education before. In addition, this research provides the development of insights and future research opportunities about sustainability in science education. Therefore, the current review aims to answer the following research questions (RQs):

RQ1. How have publications and citations progressed throughout the year?
RQ2. Which is the most cited reference, the most productive source, the institution, and the country?
RQ3. Who is the most prolific and widely cited author?
RQ4. What is the status of co-authorship for author, country, and distribution of author keywords?

2. METHOD

2.1 Design

A bibliometric analysis of sustainability studies in science education served as the study's foundation. This bibliometric review process is crucial because it contributes to the creation of a categorical perspective of the papers produced in each study field. As of this writing, the use of VOSviewer software offers the opportunity to exhibit data graphically using a category map.

2.2 Data Collection

In order to provide insights and future research prospects, graphic analysis and representation are crucial because they can aid academics and professionals in understanding what has been discovered regarding sustainable practices in the field of scientific education. Data was collected on November 24, 2022 from Scopus database. Data processed from scopus is used as the main source in document retrieval and ensures that there are no additional relevant references and reporting/study results from other sources. Before conducting further data analysis, criteria are first determined in determining the documents to be analyzed. The following criteria are applied when searching for documents, including:

Table 1. Data Search Criteria

Criteria	Detail
Database	Scopus
Topic	"sustainability "OR" sustainable" AND "science education"
Time Range	2000-2022
Language	English
Document Type	All types of documents

Document searches were carried out with the application of Boolean operators with keywords ("sustainability "OR" sustainable" AND "science education"), a total of 837 documents were obtained. The data is then limited to criteria so that the final data is obtained as many as 797 documents for analysis.

2.3 Data Analysis

The analysis done includes how publications and citations have changed over the course of the year, the references that have been cited the most, the most prolific institutions, countries, and authors, the status of co-authorship for authors, the nation, and the distribution of author keywords. The Preferred Reporting Items for Systematic Review and Meta-Analyses framework was used in this study's data

search method. (D. G. Altman, J. Tetzlaff, A. Liberati, and D. Moher, 2009), is shown in Figure 1.

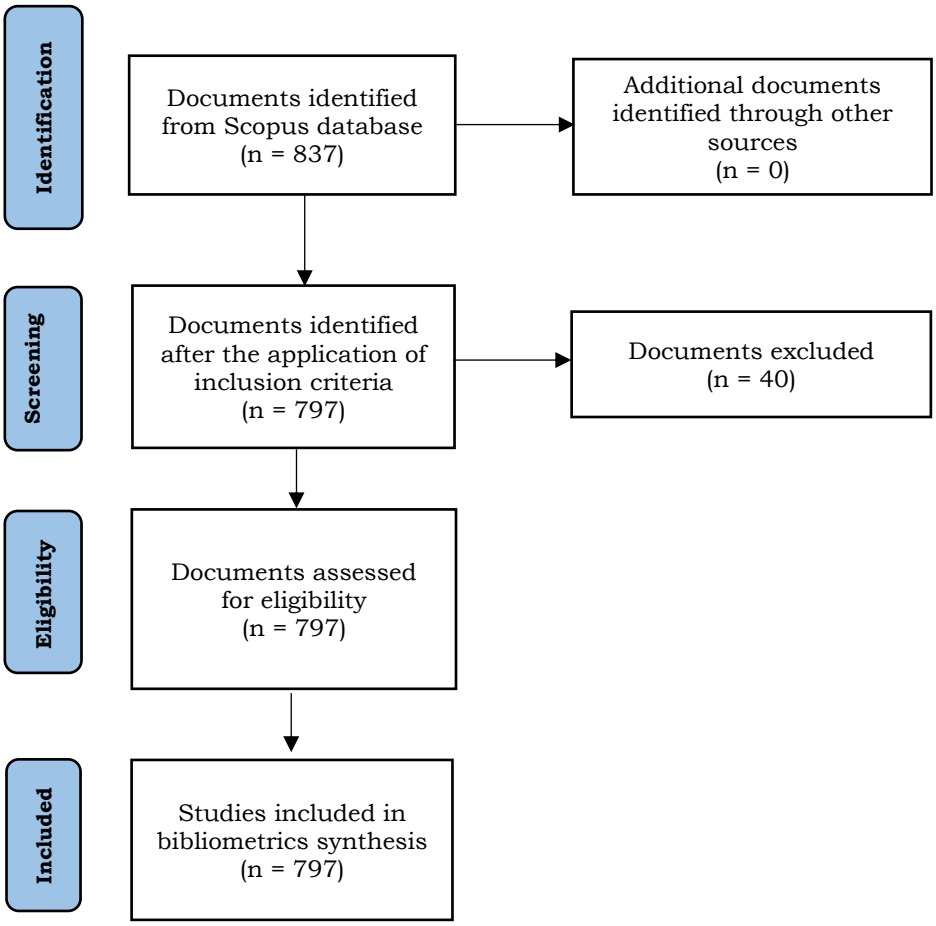

Figure 1. Data Search Process

3. RESULTS

The 797 materials that were collected are in a variety of formats, including journal articles (n = 469), conference papers (19%, n = 157), books and book chapters (12.30%, n = 98), and other sorts of documents (9.16%, n = 73). This study employs Microsoft Excel for data processing and analysis. Due to their simplicity of use and calculation, the majority of the data is given as percentages and frequencies. The VOSviewer (https://www.vosviewer.com/) application uses bibliometric network visualization, which necessitates the export of document data as a CSV file (comma-separated values) (van Eck & Waltman, 2021). Such bibliometric visualizations help to analyze the status of co-authorship for the author, the country and the distribution of author keywords. The analysis's findings will be displayed as a table and a network visualization map. A node's size indicates how many articles it owns; the bigger the node, the more articles it owns. A node's line width, on the other hand, indicates how intensely two nodes collaborate; the wider the line, the more frequently the two work together. It should be noted that terms that recur frequently together in published documents are color-coded and then grouped together.

3.1 Trends in Publication and Citation

The search results show that 799 total documents were published between 2000 and 2022. Picture. The annual publications and total citations on sustainable development in science education are shown in Figure 2 for the entire year.

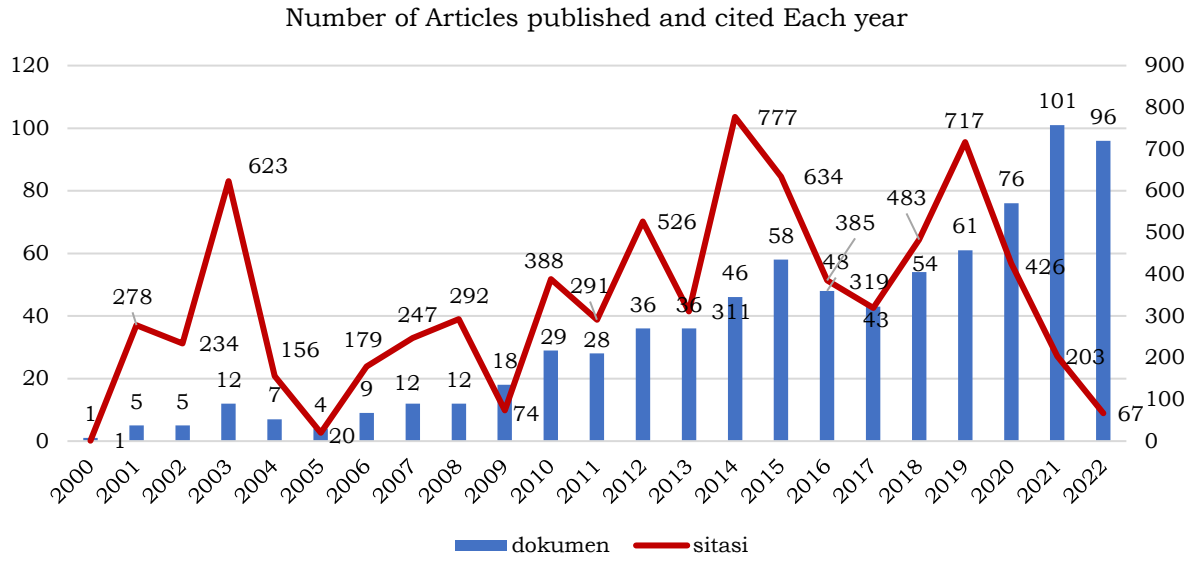

Figure 2. An Annual Breakdown of Publications and Citations

Publication distribution and citation The first essay on sustainability in science education, which will be covered in this piece, was published in 2000 and has the document number 1. With an average publication rate of 10 documents per year, there were 114 documents (14.30%) throughout the first 10 years (2000-2010). As many as 587 documents were published in the second 10-year period (2011-2021), making up 73.65% of all publications during the analysis period. This represents a significant rise in the quantity of studies in this subject. Meanwhile, the number of publications rose to 96 documents (12.05%) in 2022 (up to this analysis was done in November). Overall, the trend in the number of citations is up year over year, which is consistent with the rise in the number of publications in the subject. There have been 7,631 citations in all, which works out to 9.57 citations per document. This development shows that more scholars are becoming interested in sustainability in the context of science education.

3.2 Most Often Cited References

Table 2 lists the top ten most often mentioned documents over the course of the investigation. The most referenced references and texts are arranged according to the number of citations, Linn M.C., Clark D., and Slotta J.D. (2003) documents under the title WISE Design for Knowledge Integration rank first with a total of 272 citations. The ranking of the top two most cited articles has the title Discovering indigenous science: Implications for science education by Snively G., Corsiglia J., and Cobern W.W. (2001) with 257 citations. Then, the work of Wals A.E.J., Brody M., Dillon J., and Stevenson R.B. (2014) entitled Convergence between science and environmental education took third place with 197 citations. In general, there are 8 articles with more than 100 citations; 3.76% of documents have citations between 50 and 100; 18.32% have citations between 49 and 10; and up to 47.30% of publication documents have citations between 1 and 9. This illustrates that publications on sustainability in Science education attracted the attention of

researchers for further analysis. Of course, the number of citations in a document is one of the factors influenced by the longer the document is published to date, thus giving other authors more time to copy.

Table 2. Most Cited Documents

Authors	Title	Source	Cites
Linn et al. (2003)	WISE Design for Knowledge Integration	Science Education	272
Snively et al. (2001)	Discovering indigenous science: Implications for science education	Science Education	257
Wals et al. (2014)	Convergence between science and environmental education	Science	197
de Jong et al. (2014)	Innovations in STEM education: the Go-Lab federation of online labs	Smart Learning Environments	174
Barab & Luehmann (2003)	Building Sustainable Science Curriculum: Acknowledging and Accommodating Local Adaptation	Science Education	163
Blancke et al. (2015)	Fatal attraction: The intuitive appeal of GMO opposition	Trends in Plant Science	130
Colucci-Gray et al. (2006)	From scientific literacy to sustainability literacy: An ecological framework for education	Science Education	121
Bonnett (2007)	Environmental education and the issue of nature	Journal of Curriculum Studies	105
Chinn (2007)	Decolonizing methodologies and indigenous knowledge: The role of culture, place and personal experience in professional development	Journal of Research in Science Teaching	98
Gough (2002)	Mutualism: A different agenda for environmental and science education	International Journal of Science Education	97

3.3 Most Productive Source

In this study, 797 documents were published in 417 different publishers. The top 10 sources in terms of both the total number of documents and the total number of citations for each document are shown in Table 3.

Table 3. The Most Productive Source

Source Name	Documents	Citations
Sustainability Switzerland	53	436
Cultural Studies Of Science Education	37	423
Science Education	15	1192
International Journal Of Science Education	13	435
ASEE Annual Conference And Exposition Conference Proceedings	13	23
Environmental Education Research	12	203
Research In Science Education	11	161
Education Sciences	10	29
Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	9	35
Proceedings Frontiers In Education Conference Fie	9	21

Thus, these 10 sources have published a total of 182 documents, accounting for 22.84% of the total publications in the analysis period and with a total citation of 2983 (38.71%). The highest number of documents is owned by the journal Sustainability (Switzerland) with 53 documents and 436 citations. Followed by Cultural Studies Of Science Education and Science Education ranked 2nd and 3rd, with a total publication of 37 and 15 documents, respectively. With a total of 1192 citations, the American journal science education has the most citations per document when evaluated in this manner. Sustainability Switzerland is second with 436 citations, while the International Journal Of Science Education is third with 423 citations.

3.4 Most Popular Institutions

The analysis of sustainability in science education is done by 1563 institutions from around the world. Table 4 contains a list of the top 10 institutions in terms of productivity. There are 20 documents on this topic at Universität Bremen (GER). As a result, Universität Bremen is one of the top 10 most productive universities. The Australian Catholic University (AUS), which has published a total of 10 documents, is in second place, followed by Helsingin Yliopisto (FIN) 9 documents, as well as the University of Haifa (ISR), University of Washington (US), University of Extremadura (ESP) and Deakin University (AUS) which each has 8 document publications. In Table 4, it can be seen that the Australian state (AUS) accounts for 3 institutions with a total of 25 documents. This indicates that this topic in Australia is in demand.

Table 4. Most Popular Institutions

Institutions	Country	Documents
Universität Bremen	Jerman	20
Australian Catholic University	Australia	10
Helsingin Yliopisto	Finlandia	9
University of Haifa	Israel	8
University of Washington	United States	8
University of Extremadura	Spanyol	8
Deakin University	Australia	8
Malmö University	Swedia	7
University of Toronto	Kanada	7
University of New England	Australia	7

3.5 Best-Performing Country

Regarding country, contributors on the document's sustainability in science education theme came from 104 different country. A total of 29 countries (n=3.48%) contributed to at least 10 documents, whereas 36.89% of the countries made just one contribution. The top 10 regional country are listed in Table 5. 31.77 percent of the total data set's articles came from the top 10 country. As can be seen, the United States tops the list with 230 publications in total, followed by Australia with 61 publications, Germany with 54 publications, and the United Kingdom with 43 publications. Together, the four nations represented 48.68% of all articles throughout the analysis period. This is an indication of their leadership in the study of sustainability in science education. Table 5 lists 5 European nations, 1 Asian nation, 2 American nations, 1 Eurasian nation, and 1 Oceanian nation. Additionally, the United States demonstrated exceptional performance in terms of citations as it had a total of 2660, which was significantly more than Australia's and Germany's totals, which came in second and third, respectively.

Table 5. Best-Performing Country

Country	Documents	Citations
United states	230	2660
Australia	61	928
Germany	54	773
United Kingdom	43	619
Spain	34	429
Canada	30	400
China	26	80
Sweden	28	417
Netherlands	22	635
Turkey	22	135

Collaboration between authors in a country can be analyzed by visualization using the Vosviewer application by selecting co-authorship on the type of analysis menu and selecting the country on the unit of analysis menu beside it. Once we have determined that a country must have at least 1 document and 1 citation, we are left with 81 countries and regions that satisfy the requirements.

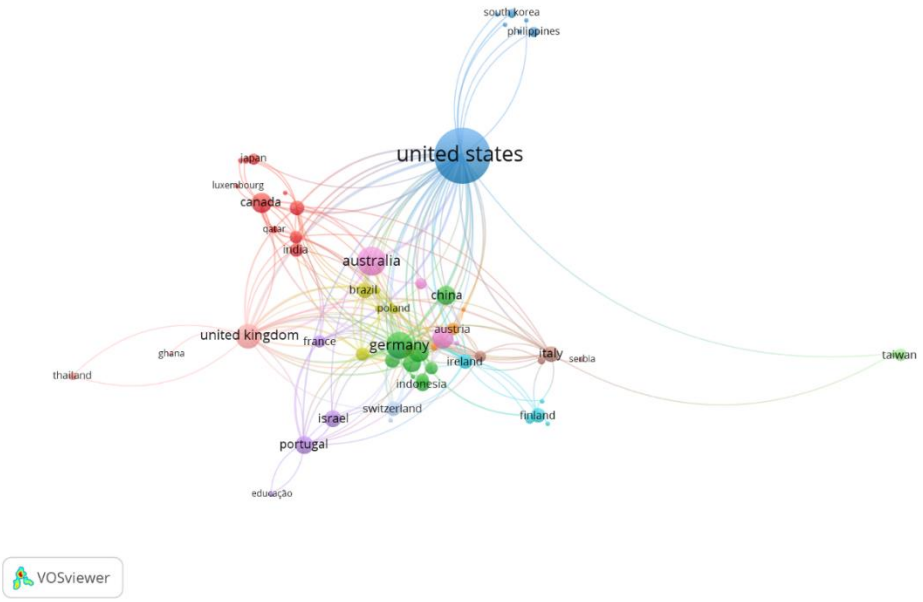

Figure 3. Visualization of Co-Authorship between Countries

Out of a total of 104, these country are grouped into 12 clusters that cooperate with one another. Figure 3 displays a map of the network of author partnerships within a country. In the first Cluster marked in red with a total of 11 countries, there was a clear collaboration between the countries of Canada (30 documents with 21 Total Link Strenght (TLS)), Norway (13 documents with 12 TLS), and India (8 documents and 13 TLS). In the second cluster which is green with a total of 9 countries, there is collaboration between the three countries, namely Germany (54 documents and 56 TLS), China (26 documents and 3 TLS) and Sweden (28 documents and 31 TLS). United states (230 documents 95 TLS), collaborated with the Philippines (8 documents and 1 TLS) and South Korea (6 documents and 2 TLS) and included the third cluster (7 countries in total) in blue. As shown in figure 4, where the United States has the largest node size when compared to other nations, it demonstrates the productivity of the United States in conducting research on this

topic, leading to the conclusion that the United States is the leading nation in publications on the subject of sustainability in science education. The United States is followed by the Australian state, Germany, and the United Kingdom, all of which have similarly sized nodes.

3.6 Most Prominent Authors

A total of 10 authors of the most prolific publications on sustainability in the field of Science education from 2000 to 2022 are presented in Table 6. Eilks, I is the most prolific because it has generated the most articles and citations of any author, with 17 publications as either lead or companion authors and 245 citations, so it is seen as a leader in sustainability publications in science education so far. Carter, L is in second place with the publication of 8 documents, while in the third position there is Zoller, U who has published 7 documents on this topic.

Table 6. Most Prominent Authors

Authors	Documents	Citations
Eilks, I	17	245
Carter, L	8	210
Zoller, U	7	117
Sjöström, J	6	136
Bögeholz, S	5	159
Tobin, K	5	38
Eggert, S	4	147
Gough, A	4	129
Zuin v.g.	4	107
Littledyke, M	4	41

The network map is used to show the amount of collaboration between authors. The visualization of the network map is made using the Vosviewer application by selecting Co-Authorship and authors. Two authors who contributed to a joint publication on the subject of sustainability in science education are represented by the co-authorship analysis. The minimum number of documents an author must have is changed to 1 in this study, and the minimum number of citations an author must have is set at 5. 788 authors from the 2017 authors met the requirement. 19 authors out of these 788 authors have strong connections, forming 5 Clusters. A different hue separates each of the groupings. The 19 writers' whole network of collaboration is shown in Figure 4. The number of documents published by the author increases with node size (N. J. van Eck and L. Waltman, 2021). The first cluster was addressed by red with a total of 7 authors namely, Eilks I. (17 documents, 32 TLS), Siol A. (4 documents, 11 TLS), and Garner N. (3 documents, 7 TLS) collaborating with each other on this topic. The blue cluster consists of 5 authors who all collaborate with each other, namely, Belova N. (4 documents, 7 TLS), Hofstein A. (2 documents, 7 TLS), Nielsen J.A. (1 document, 6 TLS), and Dittmar J. (1 document, 6 documents). The blue color is the third cluster of authors led by Zuin V.G. (4 documents, 8 TLS), Frerichs N. (2 documents, 6 TLS), and Zowada C. (2 documents, 5 TLS). The fourth cluster marked in yellow consists of 2 authors namely Blonder R. (1 document, 1 TLS), and Mamlok-naaman R. (2 documents, 2 TLS). While the last cluster is given purple with 2 authors, namely Sjöström, J (6 documents, 16 TLS) and Zidny R. (2 documents, 4 TLS).

The German writer professor Ingo Eilks from Universität Bremen is the most frequently mentioned author because it has the highest number of citations at 245, second place is author Lyn Carter from the Australian Catholic University and author

Susanne Bögeholz from Universität Göttingen in third place. Eilks I. had the highest total link strength (TLS=32) when comparing the total co-authorship strength of one author to another, followed by Sjöström, J. (TLS=16), and Siol A. (TLS=11). This shows that the three authors have a strong network of cooperation in other authors on this topic.

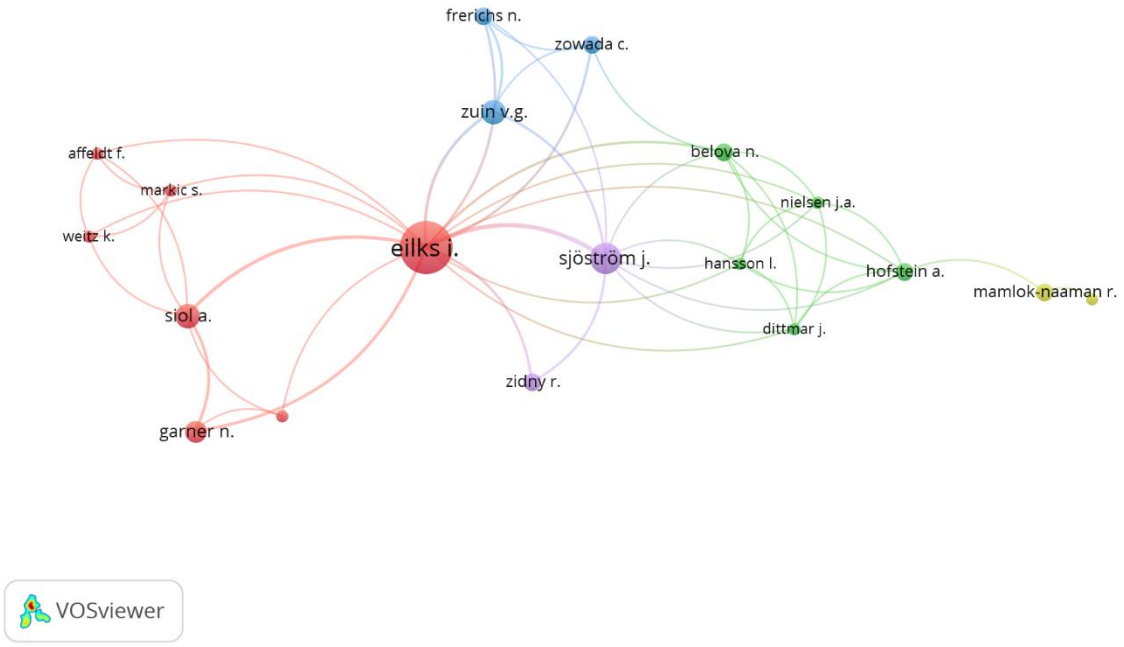

Figure 4. Visualization of Relationships Between Authors

3.7 Occurrence of Author Keywords

Vosviewer's Co-occurrence keyword analysis is used to create a map that shows the most common words and is used in titles, abstracts, and keywords on this topic. In order to prevent excessive overlap in the final word map and ensure that the 155 generated keywords match the requirement of a total of 3593 words, the minimum number of keyword occurrences is set to 5 in the first place. As seen in Table 7, the top 10 keywords all pertain to sustainability in science education and are all highly searched terms. Additionally, environmental education, learning, and planning are the most recent author keywords.

Table 7. Occurrence of Author Keywords

Keywords	Occurrence	Total Link Strength
Science Education	209	765
Sustainable Development	159	647
Education	136	643
Sustainability	109	382
Teaching	91	548
Students	80	464
engineering Education	71	396
Education computing	55	350
Computer science education	47	263
Curricula	45	263

A map of the visualization of words in the author on this topic is presented in Figure 5. On the figure. 5, it can be seen that the keywords that are most often checked according to clusters are viewed based on the largest node size in each color, namely: Sustainability (red), Education (green), sustainable development (blue), science education (yellow), teaching (purple), science and technology (cyan) and professional aspects (orange). In particular, the most commonly encountered keywords are science education (209 occurrences, 643 TLS), sustainable development (159, 647), and education (136, 765).

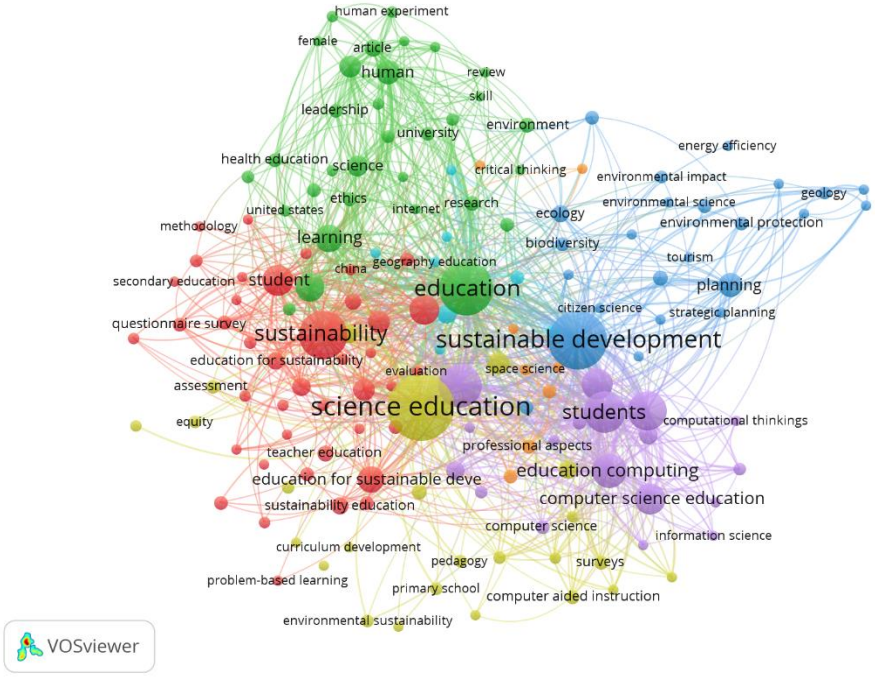

Figure 5. Visualization of Keyword Relationships

4. DISCUSSION

This research examines research related to sustainability in the field of science education starting in 2000-2022 through bibliometric analysis. Obtained 831 assorted documents from the Scopus database, but after limiting them to the search criteria (Year and Language) only 797 documents were then further analyzed using VOSviewer software. The analysis period began in 2000, documents related to sustainability in science education continued to experience a sharp increase with the highest interest in publication achieved in 2021. In 2021, it was recorded that as many as 103 documents or equivalent to 12.39% of the total documents. This suggests that the number may continue to increase in the years to come. Additionally, there was a notable rise in the quantity of citations, particularly between 2013 and 2014 and in 2019. The year with the most citations, 2014, had a total of 777, and after that the number of citations gradually decreased until it slightly increased in 2019, 2019, with a total of 717.

In terms of widely cited documents, there will be 3 groups of authors who have the top citations in one published document, namely: Linn M.C., Clark D., and Slotta J.D. (2003), Snively G., Corsiglia J., and Cobern W.W. (2001), as well as Wals A.E.J., Brody M., Dillon J., and Stevenson R.B. (2014). In the document entitled WISE Design for Knowledge Integration has the highest citation with a total of 272 citations. The document is an article written by Linn M.C., Clark D., and Slotta J.D.

in 2003 that contains the development of a Web-based Inquiry Science Environment (WISE) that serves for a flexible and adaptive learning environment. This learning applies a research-based curriculum to many science teaching thus overcoming student learning difficulties. The second document is still in the form of an article with the title Discovering Indigenous Science: Implications for Science Education with a total of 257 citations. The article discusses the use of TEK (traditional ecological knowledge) literature that is based on developing sciences and offers examples of documentation of evidence that is abundant, environmentally pertinent, and economical in indigenous sciences. Utilizing this TEK advances research, environmental awareness, and sustainability. As a result, it offers educational approaches that can support all scientific students and help them understand the differences between Western modern science and indigenous science. The article was written by Snively G., Corsiglia J., and Cobern W.W. in 2001. The last document titled Convergence Between Science and Environmental Education was written by authors de Jong T., Sotiriou S., and Gillet D. in 2014 with a total of 197 citations. The document is a review that contains cooperation between environmental education and science education so that it can form the color of a citizen science country and address concerns about sustainability.

The results of the top three quotation documents convey that there is a need for synergy or cooperation between science knowledge and knowledge possessed by residents (both traditional ecological knowledge and environmental knowledge) so that they can overcome sustainability problems and teach in class. Our findings are in line with previous studies (Østergaard, 2017), which states that this science education, both in terms of concepts connected with the knowledge of each indigenous or with the suitability of the curriculum, aims to make students better understand the meaningfulness of science in learning,

The most productive sources in the first position are occupied by Sustainability Switzerland with a total of 53 documents consisting of 50 articles, 1 editorial and 1 review. The content's focus on sustainability and the fact that some of his articles are linked to science education may be one factor in the source's high volume of publications. This source is found to have begun publishing this topic in 2015. The second position was obtained by Cultural Studies Of Science Education with a total of 37 documents. This resource discusses the study of science education which is associated with cultural studies, which serves for learning and survival (sustainability). This source is in line with the discussion in the document that is widely cited in the previous paragraph, that the interaction between science knowledge and traditional cultural studies / ecological knowledge in Education and the resulting impact is a topic of interest and much research. Then Science Education occupies the third most productive source because it has published 15 documents in the study analysis period.

On the other hand, due to differences in cultural background and technological developments in each country. This has led to a considerable difference in understanding in the topic of sustainability in science education (Grosseck et al, 2019). In the category of productive countries in the analysis period, it was found that the United States country occupied the first place in both the number of documents (230 publications) and the number of citations (2660 citations), this caused the US state to be a leader who studied a lot about sustainability in science education. Then followed by Australia in second place with 61 publications and 928 citations, the large number of documents published in Australia is in line and supported by the large number of institutions that publish on this topic which can be seen in table 5. In the table, it can be seen that Australia is a country that

contributes to 3 institutions, namely the Australian Catholic University, Deakin University, and the University of New England. Furthermore, Germany is in third place with 54 publications and 773 citations, the large number of publications in this country is supported by Universität Bremen which is the most productive institution in the first rank that has published as many as 20 documents (accounting for 37% of the total publications in Germany). Overall, the 10 most productive countries discussing this topic are OECD (Organization of Economic Co-operation and Development) member states. This is possible because there is government support in OECD member nations for the incorporation of sustainability-related themes in science education, allowing for the possibility of extensive study. One cause could be the absence of state financing for ESD-related research in poorer nations. Grosseck et al. (2019) offer another explanation for why new research coming out of OECD member states is growing so quickly. Perhaps this is due to the fact that there are more universities and research centers in OECD member states than in non-OECD countries, and these institutions require a continuous publication policy in the area of sustainable development.

The discussion of the most influential authors on this topic is, professor Ingo Eilks, who is from the Universität Bremen (Germany), is the most prolific author because it has published 17 documents with 245 citations on this topic, Eilks publications on this topic began in the last 10 years (2013-2022). In addition, Ingo Eilks also collaborated the most with other authorsstudy of the network map, which shows that 32 total links with a strength of, attests to this. Based on these three things, Ingo Eilks is one of the leading authors on the topic of sustainability in science education, although the period of study is not too long. While in the position of the second prolific author, namely, Lyn Carter with a total of 8 publications-210 citations, the author comes from the Australian catholic university which is the top 2 most productive institutions. While the third author is Uri Zoller who has 7 publications-117 citations, Zoller is a professor affiliated with the University of Haifa (Israel) which is included in the Top 4 most productive institutions. On the basis of this, it can be observed that influential writers and the most productive institutions have a relationship, with the authors having an influence on the institutions of collaboration. Vosviewer's analysis of the collaboration map yielded five distinct clusters with an average of seven to two authors per cluster. It is clear that the writers have developed extensive worldwide collaboration on the subject of sustainability in science education.

The last discussion is about the analysis of words contained in the title, abstract, and keywords, therefore co-word analysis is carried out on the vosviewer application to find out the relationship between each word that appears (irwanto et al, 2022). The results of this word analysis are displayed in the form of a word network map in Figure 5. Based on the figure, it is known that 7 clusters are formed, each of which is displayed using nodes with different colors and interconnected between clusters. The results of the analysis obtained words that often appear, namely, Science Education (209 events, 765 link strength), Sustainable Development (159, 647), Education (136, 643), and sustainability (109, 382). These frequently appearing words are not only influenced by the application of Boolean operators to keywords ("sustainability "OR" sustainable" AND "science education") but also the relationship between each word.

The relationship of the word that arises can be interpreted to mean that sustainability or sustainable development affects each other with education, especially science education. Over the past decade, sustainability development has had a significant impact on learning in science education. This may be because many

participants state that studying sustainable development in science education provides experiences and benefits in their lives. as in situations involving resource use, involvement in local discussions about sustainable development, or occupations in science and technology that are concerned with sustainability (Sjöström et al., 2015). Due to the rapid growth of sustainable development in science education, both at the high school and college levels in various universities, many authors examine how the proper implementation of sustainable development in science education, both in terms of concepts connected with the knowledge of each native or with the suitability of the curriculum aims to make students better understand the meaningfulness of science in learning (Østergaard, 2017). Additionally, the purpose of science education is to prepare students to respond to societal issues brought on by the impact of science and technology with responsible, critical, and creative thinking. This is in line with the core principles of sustainable development and will help people live better lives despite natural limitations and existing issues (Sjostrom, 2013; Stuckey et al., 2013). Thus, it is crucial to include new ideas and techniques into the teaching of science, as well as to alter the teacher education curriculum. Sustainability thinking and action is one of the topics' main sources, and the associated educational paradigm is known as Education for Sustainable Development (ESD) (Burmeister et al., 2012).

5. CONCLUSION

A bibliometric study of 797 documents in the area of sustainability in science education was done for this article. The document, which spans the years 2000 through 2022, was taken from the Scopus database. There haven't previously been any bibliometric studies of sustainable development in science education, which makes this bibliometric analysis particularly significant given the significance of the role that science education plays in the sustainability sector. This research provides a development of insights and future research opportunities on sustainability in science education. The development of publications and citations throughout the period 2000-2022 on this topic indicates that sustainability in science education is in great demand. However, as mentioned earlier in the data search criteria, that review is limited to the analysis of documents in English about continuity in science education. Therefore, it is hoped that in future research this research will be expanded to use documents in other languages for the analysis process.

Conflict of Interest

The author has no conflicts of interest to declare.

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