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Bibliometric Analysis of Research on Scientific Literacy between 2018 and 2022: Science Education Subject

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Abstract

This study presents the results of a bibliometric scientific literacy analysis on science education subjects. The main objectives of this study are (1) to analyze trends in scientific publications on scientific literacy in science education subjects; (2) identification of networks between authors, institutions, and countries; and (3) to understand the structure and focus of research and teaching themes of scientific literacy on science education subject. This research uses 451 published documents from 2018-2022 from the SCOPUS database. VosViewer software is used to analyze and visualize research data. The results of the research show (1) scientific publications on the topic of scientific literacy in science education subject have increased significantly in the last five years; (2) research results on this topic are published in reputable scientific journals (ranked Q1 and Q2); (3) United States is the country with the highest number of documents, citations, and institutions; and (4) there are six groups of keywords used, namely scientific literacy, science education, nature of science, students, education, and teacher education. This study recommends that research at the primary and secondary education levels by taking into account aspects of SL traits can be carried out in future research.

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INTRODUCTION

Scientific literacy (SL) is a simple concept in theory but not easy to explain practically (Glaze, 2018). Discussions and promotions related to SL are a step backward, like scientific discussions in the 19th century, which aimed to increase the number of scientists and engineers oriented toward economic development (Zeidler et al., 2016). SL's goals are reflected by expectations of scientific ideas that students must learn and how to learn these scientific ideas (Herman, 2018). In line with this statement, SL is defined as knowledge and understanding of science in terms of concepts and processes used to make decisions, participate in society, and economic productivity (National Research Council, 2012). SL is concept-oriented toward how scientists investigate, understand, communicate, and provide recommendations for solving scientific issues (Herman, 2018). On the other hand, it is explained that SL, in general, can be defined into three groups (Norris et al., 2014), namely (1)

states of knowing, which refer to basic knowledge about science that must be understood so that it can be used to make the right decisions regarding personal problems and groups (Foster & Shiel-Rolle, 2011). Moreover, the knowledge category emphasizes the substantive content of science and meta-scientific knowledge, namely knowledge about scientific knowledge (Chi et al., 2018; Norris et al., 2014); (2) capacities refer to social, procedural, and communicative competencies; and (3) traits refer to intellectual characteristics (inquisitiveness, open-mindedness, and carefulness) and morals (honesty, generosity, and courage) (Norris et al., 2014).

The need for SL for students and the community arises with increasing climate change, while the literacy level of students and society, in general, is still low regarding these issues. In line with this statement, Olson et al. (2015) explained that only a few science teachers understand the content, practices, and characteristics of science needed for meaningful and effective science teaching. It was further described that traditional science teaching, which is only concept-oriented and does not accommodate applications of science concepts in real contexts (Glaze, 2018; Zeidler, 2016), further strengthens the previous statement. These problems underlie the increased SL research and teaching from primary education to tertiary institutions (Şentürk & Sari, 2018). Research related to SL has been carried out in various disciplines. Boh Podgornik et al. (2017) identified information literacy (IL) correlations with SL and analyzed the achievements of university students based on the categories of remembering, understanding, and applying knowledge. The results of this study indicate that SL and IL are significantly correlated, where the IL of university students depends on the SL obtained from previous education. Furthermore, students with good SL apply knowledge from IL better than students with less SL.

SL is a cross-disciplinary study (Shaffer et al., 2019) that students use to evaluate the quality of information and scientific arguments put forward by scientists and media (Aristeidou & Herodotou, 2020). It is essential to teach and integrate SL into the education system (O'Toole et al., 2020) to prepare students to operate their science content in various real contexts (Spires et al., 2018). It was further explained that integrating SL into learning is a form of preparation for students who are aware and able to solve problems (Kuthe et al., 2020). Discussions on integrating and learning SL are still being carried out today (O'Toole et al., 2020) due to the broad context in which the term is used (Ni'mah, 2019). Bibliometric analysis needs to be carried out to synthesize the issues of teaching and research on SL in science education. Several SL bibliometric analyses in science education have been carried out, such as Ni'mah (2019), who found that SL research focuses on implementing models and teaching methods to improve students' SL. Unfortunately, this research only focuses on scientific publications related to SL in Indonesia. On the other hand, Suhaimi and Mahmud (2022) found that scientific publications on climate-change literacy had increased over the past 20 years.

This study focuses on (1) analysis of the trend of scientific publications related to SL in science education; (2) identification of networks between authors, institutions, and countries; and (3) understanding the structure and focus of the research and teaching themes of SL in science education. This study uses the SCOPUS database as a source of research data for bibliometric analysis. Bibliometric analysis is used to analyze scientific literature in specific fields of science and can assist researchers in understanding the development of science in the disciplines in their area (Wirzal et al., 2022). Furthermore, several aspects related to SL that were identified were revised to obtain data sources relevant to this study's purpose.

METHOD

Bibliometric analysis was used in this study to evaluate literature about SL that has been published in scientific journals and periodic conference proceedings. Bibliometric analysis is a technique used in research that focuses on identifying contributions, forms of relationships, and trends in the development of publications and citations over a certain period (Pham et al., 2021; Wirzal et al., 2022). The bibliometric analysis uses keywords on specific topics to identify how each scientific literature is related and develops yearly (Zupic & Čater, 2015). This technique is claimed to be suitable for exploring publication growth trends on specific topics and networks between authors, institutions, and the author's country of origin (Suhaimi & Mahmud, 2022).

Five steps (Figure 1) as (1) research design, (2) data collection, (3) data analysis, (4) data visualization, and (5) discussion (Hernández-Torrano & Ho, 2021) were carried out in this study. Network analysis was reviewed based on co-authorship, citation, and keyword analysis (Le Thi Thu et al., 2021). Co-authorship analysis involves the relationship between authors, countries, and institutions that publish research results related to SL. Furthermore, citation analysis includes journal citations received based on the number of scientific article citations issued on SL. Citation analysis aims to identify the relevance of the SL topic with different topics from different scientific journals. Finally, the analysis of keywords seeks to identify the main topics, topic extensions, and research issues in SL in science learning. This study uses co-occurrence with all keywords to determine the relationship keywords in the title, abstract, and scientific journal metadata.

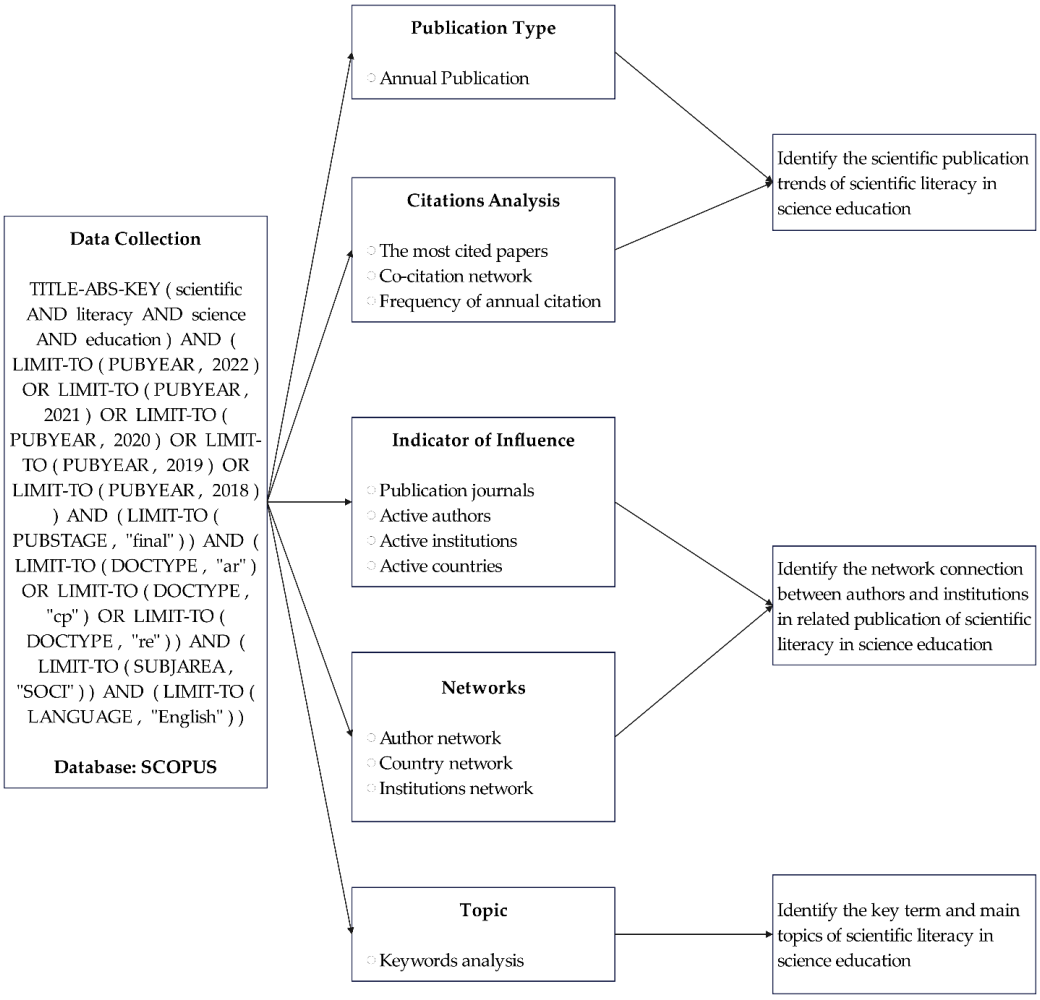

Figure 1. The current research framework

Table 1 shows the application of keywords in searching literature related to SL in science teaching. In the initial search, 2201 documents were found with the keywords *scientific AND literacy AND Science AND education*. Improvements were made by entering the publication year limit, namely in the last five years (2018-2022). Found 925 scientific publication documents in the English language span of years and types of journal articles, seminar proceedings, and article reviews. However, the research subjects were still general, so filtering was done by limiting the search subjects to *SOCIAL SCIENCES* area subjects only. There are 451 documents used in the analysis stage.

Table 1. The query string and the total document obtained

Query string	Total documents
TITLE-ABS-KEY (scientific AND literacy AND science AND education)	2201
Refine I	
TITLE-ABS-KEY (scientific AND literacy AND science AND education) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018))	925
Refine II	
TITLE-ABS-KEY (scientific AND literacy AND science AND education) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (LANGUAGE , "English"))	451

The SCOPUS database collects scientific publication data based on scientific literacy keywords. SCOPUS is an indexing agency and a leading database containing metadata of scientific articles published in reputable scientific journals. Wirzal et al. (2022) stated that the SCOPUS database combines abstracts and citations from various reputed scientific journals and disciplines, making it very relevant as a source of bibliometric research data. Data mining was obtained from the SCOPUS database (451 documents) was then analyzed using Ms. Excel and VosViewer to visualize research trends (Prahani et al., 2022) SL in science education.

RESULTS AND DISCUSSION

Trends in Scientific Publication of Scientific Literacy in Science Education

Identification of publications and citations aims to describe the development of research and publications related to SL in the last five years (2018-2022). Figure 1 shows development trends and publication excerpts on the SL topic in the 2018-2022 range. There are 451 documents published in scientific journals and procedures selected for bibliometric analysis. Based on the research results, the number of publications related to the topic of SL in science education has increased significantly in the last five years. The number of scientific publications has grown since 2018-2021, from 76 documents (2018) to 112 papers (2021). Publications on SL in science education will decrease to 98 records in 2022. The results of this

study show that SL is an important research topic and competency in science education. The rapid development of technology has made it easier to obtain information and knowledge transfers (Hsu et al., 2022). The validity and reliability of this information and knowledge need to be checked or evaluated (Haug & Mork, 2021) to avoid misconceptions and even wrong concepts among students (Spector & Ma, 2019). This description is relevant to the increasing number of publications and teaching of SL in science education. SL is stated to be very important in learning to train students to evaluate the quality of information, argumentation, and knowledge possessed to solve problems (Aristeidou & Herodotou, 2020).

The number of citations consistently increased significantly every year (Figure 2). The results of this study indicate the high impact factor of SL publications and the close attention of researchers/teachers to SL in practical science teaching. The number of citations provides an overview of the synergy between previous and recent research and the importance of specific topics to be studied. It was further explained that citations have five important objectives, (1) to provide an adequate research context to provide space for readers to evaluate the justification of the author's conclusions, (2) to provide a source of research background, (3) to build research credibility, (4) provide examples of alternative ideas, data, and conclusions (compare/contrast), and (5) give credit to previous studies that are relevant to the research being conducted (Mack, 2018).

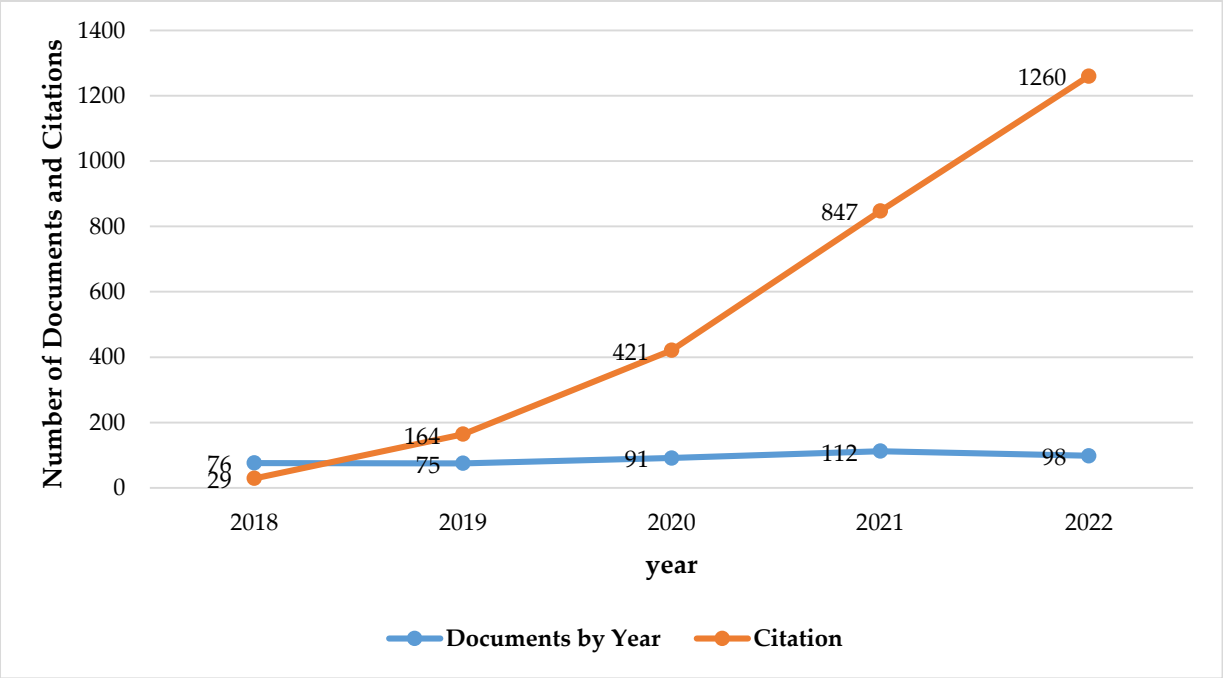

Figure 2. Trends in SL publications and citations in the context of science education over the past five years

Citation Analysis of Journals

Table 2 shows the ten scientific journals that have contributed the most to the topic of SL in science education in the last five years (2018-2022). This section presents the number of documents, citations, quartiles, 2021 cite score and impact factors from each of the ten journals analyzed for ranking purposes.

Table 2. The top 10 most active journals publishing scientific literacy in the last five years

Rank	Source	No. of Documents	No. of Citation	Quartile	Cite Score 2021	SJR
1	International Journal of Science Education	29	240	Q1	4.1	1.15
2	Science and Education	21	266	Q1	3.1	0.94
3	Education Sciences	17	95	Q2	2.9	0.52
4	Sustainability	17	95	Q1	5.0	0.66
5	Research in Science Education	13	57	Q1	7.3	1.7
6	Cultural Studies of Science Education	9	35	Q1	2.3	0.9
7	Eurasia Journal of Mathematics Science and Technology Education	9	46	Q2	4.4	0.57
8	Frontiers in Education	8	7	Q2	2	0.58
9	Journal of Research in Science Teaching	8	149	Q1	9.3	2.71
10	Jurnal Pendidikan IPA Indonesia	8	75	Q2	3.3	0.46

Based on the results of the analysis, the *International Journal of Science Education* has been the most influential scientific journal in the last five years in terms of SL in science education, with 29 published documents and 240 citations, followed by *Science and Education*, with 21 published documents and 266 citations, *Education Sciences*, and *Sustainability* with every 17 papers and 95 citations each. For the rest, each scientific journal contributes as many as 8 to 13 documents with 7 to 149 citations (Table 2). The results of this analysis show that there are several articles with high quality and citations from researchers on the topic of FS in science education (Djeki et al., 2022).

The results of journal analysis show that journals that publish the results of SL research in science education are journals with high rankings, namely Q1 and Q2 in the SCOPUS database (Table 2). Based on the results of the analysis, it is known that six journals are ranked Q1, and four journals are ranked Q2. *International Journal of Science Education* is the most influential journal in the publication of the integration of SL in the science education curriculum, the integration of SL in science learning using learning models that are generally used in science classes such as project-based learning, inquiry-based science, and evaluation of SL in science learning. The analysis results show that these scientific journals are very relevant to the research topic and are included in the category of journals with a high impact factor in the last five years. *The Journal of Research in Science Teaching* has the highest Cite score indicator compared to the top 10 other scientific journals with a rating of 9.3, followed by *Research in Science Education* (7.3 ratings), and *Sustainability* (5.0 ratings). The three scientific journals are ranked as Q1 journals so that it can be stated, if a journal has a high cite score, then the journal will be indexed Q1 in the SCOPUS database (Suhaimi & Mahmud, 2022).

Figure 3 shows a network of journals that publish research results or review articles related to FS in science education. *The International Journal of Science Education* is the most

productive and influential journal, as seen from its extensive network of citations with other scientific journals that publish the same topic.

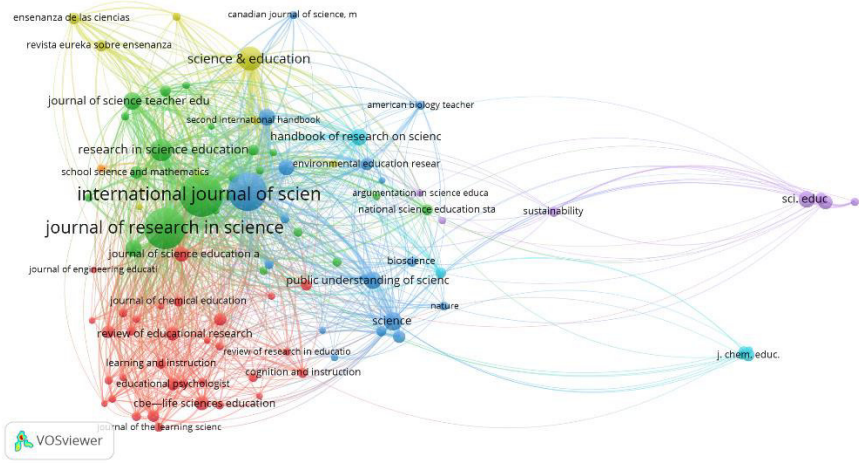

Figure 3. The most influential journals in SL publications in science education.

Contributions by Author

Table 3 shows information regarding the top 10 authors and the number of published documents, citations, and h-indexes. Referring to the analysis results, writers from Columbia institutions are included in the top 3 most productive on the topic of SL. However, the three authors are identified as collaborating in many publications, so that they have the same number of documents and h-indexes. Apart from the authors who were included in the top three groups, the number of documents from other authors did not differ significantly between 3 to 5 papers with similar h-indexes between 2 to 3.

Table 3. Top 10 authors in SL in science education based on the total number of publications

Rank	Author	Institution	Country	No. of Articles	No. of Citations	h-Index
1	Archila, P.A.	Universidad de Los Andes	Colombia	9	64	5
2	de Mejía, A.M.T.	Universidad de Los Andes	Colombia	9	64	5
3	Molina, J.	Universidad de Los Andes	Colombia	7	63	5
4	Forbes, C.T	School of Natural Resources	US	5	28	3
5	Restrepo, S.	Universidad de Los Andes	Colombia	4	10	2
6	Sadler, T.D.	The University of North Carolina at Chapel Hill	US	4	26	2
7	Baram-Tsabari, A.	Technion - Israel Institute of Technology	Israel	3	5	2
8	García-Carmona, A.	Universidad de Sevilla	Spain	3	28	2

Rank	Author	Institution	Country	No. of Articles	No. of Citations	h-Index
9	Lavonen, J.	University of Johannesburg	South Africa	3	33	2
10	Lederman, N.G.	Illinois Institute of Technology	US	3	31	2

Based on the results presented in Table 3, Archila, PA and de Mejía, AMT from Columbia are ranked first with nine documents and 64 citations, followed by Molina, J. (Columbia) with seven documents and 63 citations, and Forbes, CT (US) with five documents and 28 citations. There are two authors with four documents: Restrepo, S. (Columbia, ten citations) and Sadler, TD (US, 26 citations). The other four authors have three documents, namely Baram-Tsabari, A. (Israel, five citations), García-Carmona, A. (Spain, 28 citations), Lavonen, J. (South Africa, 33 citations), and Lederman, NG (US, 31 citations). All of the authors included in the top 10 are expert researchers on the topic of SL in science education. On the other hand, Figure 4 shows collaboration between authors with at least two published documents. The analysis results show that the four research groups are related. The analysis results also show a strong relationship and collaboration between researchers regarding research on the topic of SL in science education.

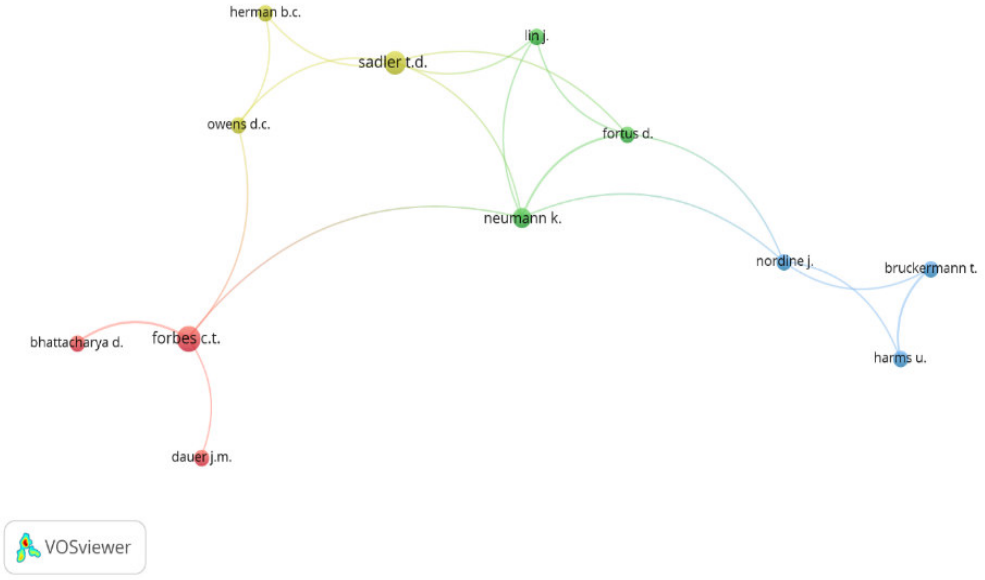

Figure 4. Co-authorship network of authors with at least two documents published

The Most Influential Papers

A list of the top 10 published articles from a total of 451 documents in the last five years (2018-2022) is presented in Table 4, along with the number of citations obtained over the five years. Based on the research results, an article titled "The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: A multilevel analysis" written by Hu et al. (2018) from China is ranked first with 117 citations. This study discusses the conceptualization of ICT and evaluates its relationship with SL, thus obtaining the highest number of citations. Furthermore, the article was published in a journal with a Q1 category (SJR = 3.86), which shows the article's credibility as a relevant reference for SL research in science education.

Table 4. The most influential papers in the last 5 years

Rank	Document title	First Author	Affiliation	Citations	Citations evaluation
1	The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: A multilevel analysis	Xiang Hu	The University of Hong Kong, China	117	1, 14, 21, 30, 51
2	The Role of Mathematics in interdisciplinary STEM education	Katja Maass	University of Education Freiburg, Germany	56	0, 0, 4, 17, 33
3	Reconceptualizing nature-of-science education in the age of social media	Dietmar Höttecke	University of Hamburg, Germany	47	0, 0 4, 16, 25
4	Scientific literacy for democratic decision-making	Hagop A. Yacoubian	Haigazian University, Lebanon	47	1, 3, 16, 9, 18
5	Visual literacy in bloom: Using bloom's taxonomy to support visual learning skills	Jessie B. Arneson	Washington State University, US	46	1, 11, 7, 13, 13
6	A mixed research-based model for pre-service science teachers' digital literacy: Responses to "which beliefs" and "how and why they interact" questions	Erhan Güneş	Ahi Evran University, Turkey	41	0, 11, 9, 14, 7
7	A Critical Review of Students' and Teachers' Understandings of Nature of Science	Hernán Cofré	Pontificia Universidad Católica de Valparaíso, Chile	38	0, 0, 8, 10, 20
8	Forms of inquiry-based science instruction and their relations with learning outcomes: evidence from high and low-performing education systems	Anindito Aditomo	University of Surabaya, Indonesia	36	0, 0, 4, 14, 17
9	Teaching and learning science in the 21st century: Challenging critical assumptions in post-secondary science	Amanda L. Glaze	Georgia Southern University, US	36	1, 2, 15, 10, 8
10	Students' environmental NOS views, compassion, intent, and action: Impact of place-based socioscientific issues instruction	Benjamin C. Herman	University of Missouri, US	35	1, 4, 9, 10, 11

Contribution by institutions

Table 5 shows the top 10 institutions or organizations that publish research results related to FFS in science education. Based on the results of the analysis, it was found that 451 published documents were produced by 953 different institutions or organizations. Based on the results of this study, four institutions from the US have the total documents related to this research topic. The National Taiwan Normal University (Taiwan) ranked first. Universidad de Los Andes (Columbia) in the second rank with nine articles, followed by the University of Nebraska (US) with eight articles, Illinois Institute of Technology (US), Stanford University (US), University College London (UK), and Beijing Normal University (China) both have six articles. The remaining institutions both have five published documents. The results of this study prove that the US is very active in developing and researching trending research topics (Djeki et al., 2022) and is a dominant country in scientific research, as presented in Table 5 and Figure 5.

Table 5. Top 10 institutions based on the number of publications

Order	Institutions	Country	No. of Articles	No. of Citations
1	National Taiwan Normal University	Taiwan	9	80
2	Universidad de Los Andes	Colombia	9	64
3	University of Nebraska	US	8	39
4	Illinois Institute of Technology	US	6	59
5	Stanford University	US	6	55
6	University College London	UK	6	44
7	Beijing Normal University	China	6	63
8	University of Johannesburg	South Africa	5	21
9	Universitat de Barcelona	Spain	5	16
10	The Ohio State University	US	5	37

Contribution by countries

Table 6 shows an analysis of the contributions of the top 10 countries with the highest number of publications and citations in the last five years. Based on the analysis results, most publications on SL topics in science education were produced by authors from the US, with 134 publications (30%). Other countries that contributed further were Spain (42 publications, 9%), Indonesia (29 publications, 6%), Germany (26 publications, 6%), China and Turkey (32 publications, 5% each), the UK (22 publications, 5%), Australia (21 publications, 5%), Taiwan (18 publications, 4%), and Canada (14 publications, 3%).

Table 6. Top 10 countries' contribution to SL in science education publications

Rank	Country	No. of Articles	%	No. of Citations	%
1	United States	134	30%	1058	39%
2	Spain	42	9%	312	11%
3	Indonesia	29	6%	179	7%
4	Germany	26	6%	229	8%
5	China	23	5%	127	5%
6	Turkey	23	5%	118	4%
7	United Kingdom	22	5%	171	6%
8	Australia	21	5%	161	6%

Rank	Country	No. of Articles	%	No. of Citations	%
9	Taiwan	18	4%	143	5%
10	Canada	14	3%	51	2%

The US is again the country with the highest ranking in terms of the number of citations based on countries with 1058 citations (39%), followed by Spain with 312 citations (11%), and Germany with 229 citations (8%). The remaining countries have several citations between 51 to 179 (2%-7%). Based on these results, it can be stated that the US and European countries are the countries that have contributed the most to SL publications in science education in the last five years. Furthermore, co-authorship analysis was carried out to identify author collaborations based on country of origin with the criteria of having at least five publications on the topic of SL in science education. Figure 5 shows the countries and authors involved in collaborating publications on the issues identified in this study.

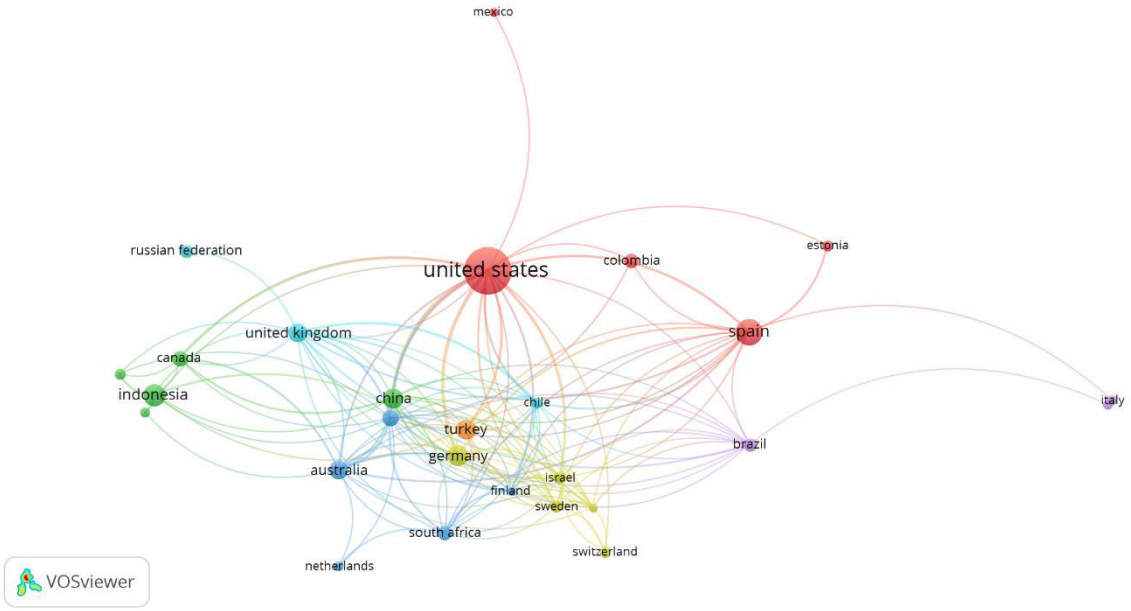

Figure 5. The co-authorship between countries

Based on the results of the analysis, 29 countries are interconnected. These results show that researchers from these countries collaborate in SL research in science education. Italy, Estonia, Mexico, and Russia are countries with a weak level of collaboration with other countries. These countries are connected less with other countries than countries with a strong group of cooperation.

Keywords analysis

Keyword analysis shows research topics based on keywords used in published documents (Goksu, 2021). Figure 6 shows 1771 keywords that are connected and appear 5 times. Each keyword is indicated by a circle and connected with a line which shows the strength of the relationship between groups of keywords. The study results show that six keywords are used in SL research in science education: scientific literacy, science education, nature of science, students, education, and teacher education. Based on the visualization results, it can be seen that SL research and teaching in science learning focuses more on integrating SL into the university curriculum with biology as the dominant subject. The

research gap is seen in the lack of integration or implementation of FS in science education for primary and secondary education levels. In addition, the emphasis on SL traits aspects in science learning is still rarely done, as seen from the weak relationship between the *efficacy* keyword and the *scientific literacy*, *learning*, *teacher education*, and *nature of science keywords* in the visualization of the analysis results (Figure 6).

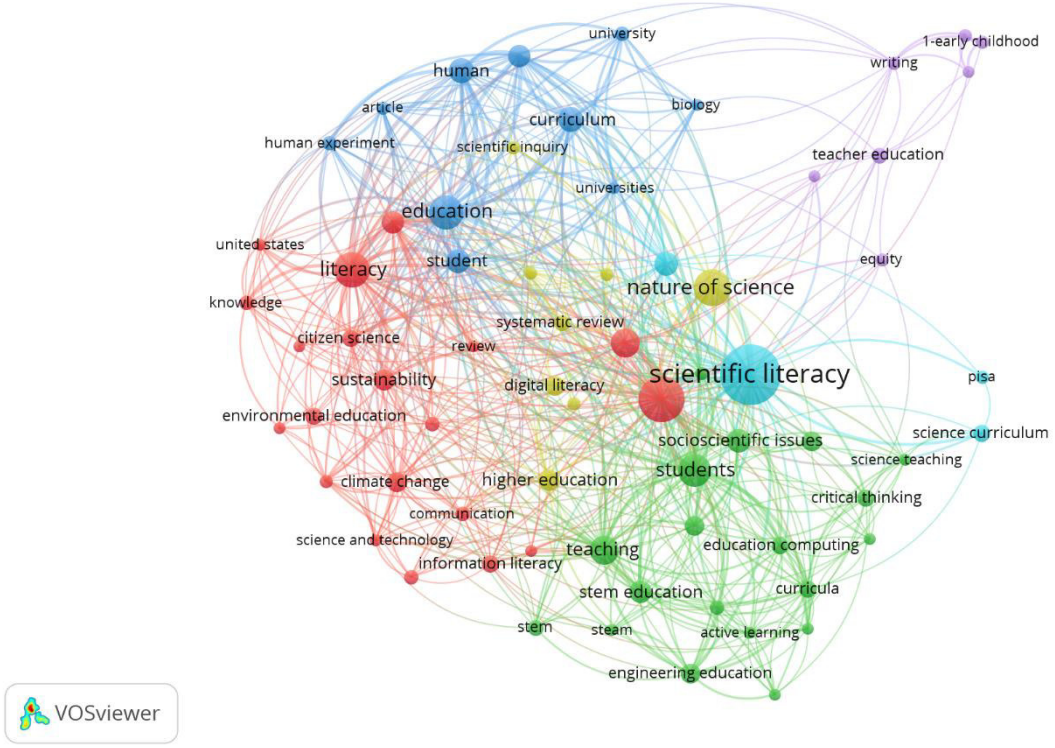

Figure 6. Co-occurrence of 1771 keywords in SL in science education subject

CONCLUSION

In line with the increasing interest in research and publications related to scientific literacy (SL) in science education, a bibliometric analysis to identify trends and the development of publications based on this theme has been carried out. The results show that publications related to SL in science education have increased significantly over the last five years (2018-2022). A significant increase in the number of citations each year also accompanies the rise in the number of publications on this topic. The results also show that journals that publish research results and review articles related to this topic are reputable journals with high impact factors (ranked Q1 and Q2). The United States has had the highest number of documents, citations, institutions, or organizations contributing to the SL topic in science education over the last five years. Furthermore, the keyword analysis results show that research in the last five years has focused more on integrating SL into university curricula with biology as the dominant subject.

RECOMMENDATION

The results of this study indicate that the integration of SL into science education for primary and secondary education levels needs to be studied in the future. Moreover, the emphasis on traits aspects in science learning needs to be further investigated given the weak relationship between the *efficacy* keywords and the *scientific literacy*, *learning*, *teacher education*, and *nature of science keywords*, as shown in the research results section.

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Declaration of Interest
The authors declare no conflict of interest.

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