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Meryem Konu Kadirhanoğulları
Kafkas University, Turkey

Esra Özay Köse
Ataturk University, Turkey

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Abstract

This study aims at a detailed analysis of bibliometric studies in science education through articles published in peer-reviewed journals. The bibliometric network analysis performed on 846 articles in the Scopus database was conducted on the bibliographic data obtained using the VOSviewer program. In the citation analysis phase, the bibliometrix program, Lotka's law and author impact ratio measurements were used. The results obtained provide trends in the field of science education and important clues for researchers. According to the results obtained, it was determined that the most studies were carried out in 2022, according to years. According to the keyword analysis, it showed that the most frequently used keywords in articles were "education", "research", "bibliometrics", "citation analysis". Looking at the most frequently used terms, the terms "research productivity", "pandemic", "h index", "average" are respectively according to their high relevance scores. It has emerged that the most cited countries are the Spain, America, China, Brazil respectively. "Scientometrics", "Sustainability (Switzerland)", "Computers and Education", "Journal of the American Society for Information Science and Technology" are the most cited journals in studies.

Introduction

One of the problems that arise in countries today is due to the deficiencies in acquiring information and awareness. An unconscious and uneducated society cannot realize that the world in which it lives will be used by people after it (Yüksel, 2009). Education is a guide in the improvement and development of people's thoughts, behaviors and lives (Acar, 2011). Depending on the changing world, the needs of the society are also changing rapidly. For this reason, it is necessary to conduct research on education in order to train the manpower that can meet the needs of people. Especially in recent years, advances in science and technology have a profound effect on the education system of countries, as in every field. Considering that science is the basis of technological advances, it is seen that in parallel with these developments, countries' orientation to these fields has increased and they focus more on science education in the education policies they prepare (Çiltaş, Güler & Sözbilir, 2012).

Science plays a critical role in the development of countries. In order to survive and lead in the field of science and technology, all countries attach special importance to science education with the aim of equipping individuals

with the desired qualifications. Efforts to improve the quality of science education continue in order to stand out in this science and technology race (Ayas, 1995).

Science is a set of intellectual and practical disciplines that foster causality, curiosity and purpose, and systematically examine facts and claims through experimentation, observation and thought. The main aims of science education can be summarized as follows: "It aims to make students individuals who are interested, discover, question, make the right decisions, solve problems, understand and use new technologies, and develop new ones. Moreover, one of the main purposes of science education is to educate individuals who can keep up with the rapidly changing and developing science age and benefit from the latest technological inventions in every field, and to teach that science is necessary in all technological inventions and developments. As a research course in science lesson, it is aimed to teach scientific operations to students. Scientific operations are used to investigate the physical world and to help students develop concepts through active learning experiences (Wolfinger, 2000).

One of the most important indicators of the development of a country's education system is scientific research in the field of education. The fastest and most accurate way to share and deliver the results of scientific research with other researchers is scientific journals. In this context, scientific journals in the field of education are extremely important for the development of education. However, the debate about the quality of the articles in these journals continues. Because a certain standard has not been achieved in terms of form, method and ethics for the articles published in scientific journals (Arık & Türkmen, 2009).

Particularly, the contribution of scientific research on science education to this field and the quality and quantity of these researches are closely related. Today, however, there are many independent studies on each subject. Therefore, inquiring about the quality and quantity of research is of great importance to understand the quality of these studies and also provides important and revealing information for other researchers in that field (Bacanak et al., 2011). In this context, research and scientific articles can help new researchers improve their knowledge and understanding by providing guidance on previous studies (Henson, 2001; Tsai and Wen, 2005). Because, people who do research should first seek answers to questions such as "what are the previous studies in the literature", "what issues and problems will be needed to work on" and "what are the ways to meet these needs and how to solve them" (Karamustafaoğlu, 2009; Şimşek. et al., 2008). However, determining trends by reviewing and organizing research in the field of science education at certain periods is important in terms of guiding scientists who want to work in the relevant field (Çiltaş et al., 2012). This situation requires that such studies be examined with content analysis (Gul and Kose, 2018).

In academic research, one of the points that researchers attach importance to is reaching and sharing the studies done to the relevant people. In particular, conducting and publishing studies in the field of education is of great importance in terms of reviewing, arranging, designing and changing the education systems that are effective in the development of countries or societies (Çepni and Küçük, 2002; Mortimore, 2000). However, the fact that these studies conducted and published are on different fields and subjects leads to the presence of many independent studies in the related literature. Therefore, content analysis studies are carried out at regular intervals in order to prevent the increasing number of studies and the different results obtained on the same subjects from causing

conceptual confusion and to shed light on the researchers in the relevant field by determining the trends in educational research (Cohen, Manion, & Morrison, 2007).In the pool, which contains many related or unrelated studies, the evaluation of the studies and the creation of a general picture are provided by the content analysis method. At the same time, content analysis studies in a field such as science education are a valuable resource that should be consulted and useful for future researchers in this field, in terms of summarizing published studies under certain categories with a holistic approach. Therefore, content analysis studies offer science educators the opportunity to follow trends in national and international literature related to their fields. This allows studies that go beyond frequently researched topics and make new contributions to the relevant literature (Çalık, Ünal, 2013; Coştu and Karataş, 2008).

Bibliometric analysis is a widely used rigorous method for researching and analyzing large volumes of scientific data. In addition to revealing the evolution of a particular field, this methodology allows us to illuminate various issues in that field (Donthu et al., 2021). Bibliometric analysis is an effective method used to analyze the relationships between journals from a quantitative perspective, to determine the state of knowledge and research trend of the field of discovery by scanning a wide range of academic literature, to explain the collaboration between countries, the citation relationships between authors and the general structure of the research field (He et al., 2020).Scientists have stated that bibliometric techniques are a method that provides an interdisciplinary approach in effectively mapping topics and themes in a research field (Khanra et al., 2020, 2021; Liao et al., 2018; Martínez-L´opez et al., 2018; Tandon et al., 2021).

When the literature is examined, bibliometric analysis has been applied by many researchers from different disciplines to detect trends in research (Azer, 2017; Çelik et al., 2021; Çetinkaya and Çetin, 2016; Karagöz and Ardıç, 2019; Kulak 2018; Kulak and Çetinkaya 2018; Kumar et al., 2021; Moral-Muñoz et al.,2020; Polat et al., 2013; Zhang et al., 2022). However, no research has been found that makes bibliometric analysis of bibliometric studies in science education. Therefore, this study is very important for a researcher who wants to do bibliometric research in the field of science education in order to have information about the researches.

The main purpose of this study is to reveal the content analysis and trends of bibliometric analysis studies carried out in science education. In this context, articles on bibliometric studies on science education scanned in the Scopus database were examined in detail with bibliometric network analysis. The bibliometric analysis conducted aims to find answers to the following questions:

1-How does the distribution of studies on bibliometric articles in science education change over the -years?

2-What is the diversity and distribution of keywords used in science education bibliometric articles?

3-What are the terms frequently used in science education bibliometric articles?

4-What is the distribution of the countries where studies on science education bibliometric articles are conducted?

5-What is the distribution of author citations in science education bibliometric articles?

6-What is the distribution in which journals the studies on science education bibliometric articles are concentrated?

Method

Data Collection Process

Scopus database was used to identify bibliometric research articles in science education. Scopus is accepted as the most comprehensive and bibliographic resource (Çelik et al., 2021; Kulak et al. 2019). Data are from the online version of the Scopus database on December 6, 2022. All records with the phrase "bibliometric and science education" in "article title, abstract, keywords" were accessed. Accordingly, 1152 documents containing the word "bibliometric and science education" were found. Later, the document type was limited to a total of 846 articles created as "articles". No language restrictions are considered. The years of accessed publications are between 1974 and 2023.

Analysis of Data

Bibliometrics is a tool used to map the state of the art in a given field of scientific knowledge. Therefore, the use of bibliometric analysis to identify and analyze the scientific performance of authors, articles, journals, institutions, and countries through the analysis of keywords and citation counts constitutes a key element that provides researchers with tools to identify pathways (El Mohadab, 2020). Bibliometric analysis is an integral part of research evaluation methodology, especially in scientific and applied fields. This method examines various aspects of science and is increasingly used in rankings of institutions and universities around the world (Ellegaard & Wallin, 2015). The reason why we chose bibliometric network analysis in our study is that this method is ideal for the continuous accumulation of bibliometric research in the field of science education and for summarizing the complexity of the literature in this field in a more understandable way on a holistic and temporal plane. Additionally, another reason for using bibliometric network analysis is the ability to visualize scientific research and identify relationships between specific topics, journals, authors, institutions or countries (Van Eck and Waltman, 2010: 523-538).

VOSviewer is a software tool developed to effectively create, analyze and visualize bibliometric networks (Van Eck and Waltman, 2017).The program is used to create maps of publications, authors, or journals based on a citation, co-citation, or bibliographic link network, or to create keyword maps based on a co-occurrence network (Van Eck & Waltman, 2011).In this research, bibliometric analysis of 846 publications was carried out using the VOSviewer v.1.61 (Center for Science and Technology Studies) program. The findings obtained from various data such as publication years and country rankings were subjected to a detailed evaluation using methods such as frequency, relationality, clustering and time analysis. Frequency represents the frequency in the network maps of the text and bibliometric data that constitute the units of analysis. This principle is a basic measure of how many times a unit is used in analysis. Relationality refers to the level of relationship between bibliometric data determined by frequency, that is, it reflects the state of coexistence. Units with high interest were transferred to the network map by the program, while units with low interest were excluded (Al et al., 2012; Tindall and Wellman, 2001). In addition, within the scope of citation analysis in the research, the bibliometrix program was used for lotka's law and author effect ratio. Bibliometrix is an R statistical package for analyzing and visualizing the bibliographic data from WoS and Scopus databases (Derviş, 2019).

Findings

Distribution of Publications by Years

When the trend of 846 bibliometric articles in science education is examined in Figure 1; It is seen that the studies related to the subject started in 1974, after 2011, the studies gained a significant acceleration, and there was fluctuation in the studies from 2008 to 2015. It is seen that the number of studies has increased continuously since 2015 and peaked with a total of 206 studies in 2022. The increasing number of articles devoted to bibliometric studies in science education after 2015 can be explained as proof that this subject has a necessary and important place among academics.

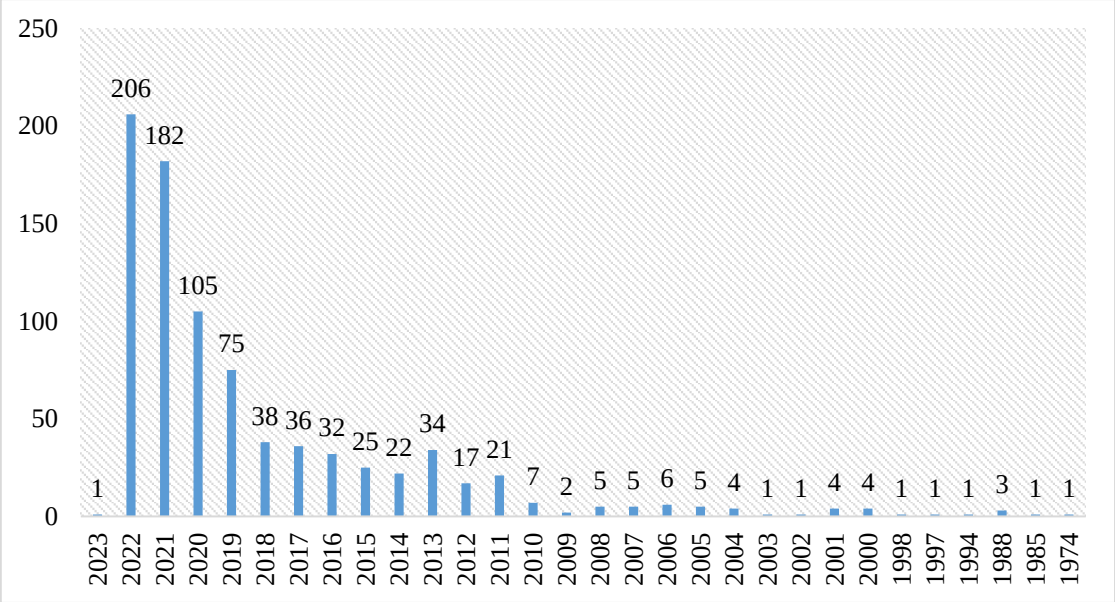


Figure 1. The Distribution of the Number of Bibliometric Articles in Science Education by Years

Keyword Analysis: Most Common Keywords in the Article

Keyword analysis is one of the essential elements of a research. This analysis can clearly show the research boundaries and progress of a piece of information (He, 1999). In this context, keyword analysis was carried out to determine basic keywords. During the analysis process, 4 keywords were accepted as the minimum repetition of a keyword, and 140 of 2097 keywords that met this criterion were selected. By calculating the total strength of each keyword's connections with others, the keywords with the highest total connection strength were selected for network analysis (see Table 1). The image created with Vosviewer for keyword analysis is given in Figure 2.

Table.1. Examining the Publications in Terms of Keywords

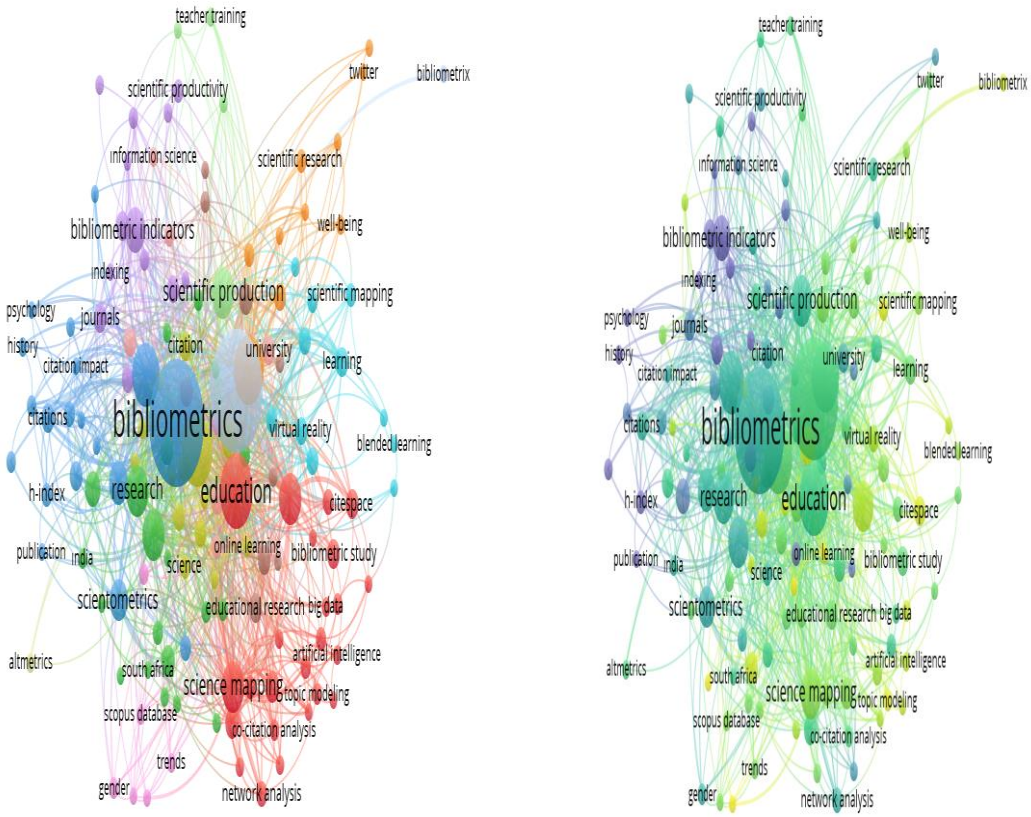
Keyword	Occurrences	Total link strength	Keyword	Occurrences	Total link strength
bibliometrics	204	322	scientific collaboration	6	15
bibliometric analysis	187	317	scientific journals	6	17

Keyword	Occurrences	Total link strength	Keyword	Occurrences	Total link strength
education	71	164	stem education	6	10
bibliometric	66	115	topic modeling	6	7
higher education	62	145	ınformation literacy	6	16
web of science	52	127	ınternationalization	6	12
scientific production	35	97	altmetrics	5	6
research	34	62	artificial intelligence	5	10
vosviewer	34	93	bibliographic coupling	5	13
citation analysis	33	67	bibliometric studies	5	8
science mapping	33	84	big data	5	9
bibliometric indicators	26	43	Cuba	5	10
Scopus	24	62	data analysis	5	14
scientometrics	23	49	databases	5	11
covıd-19	21	60	dentistry	5	10
publications	16	24	digital competence	5	17
nursing	14	40	education research	5	7
social network analysis	14	29	evaluation	5	7
literature review	13	34	history	5	5
review	13	28	online learning	5	19
systematic review	13	26	public health	5	6
citations	12	25	scientometric	5	9
citespace	12	24	scimat	5	12
ımpact factor	12	28	Scopus database	5	13
bibliometric study	11	10	Spain	5	11
bibliometry	11	20	SSCI	5	10
citation	11	22	teacher training	5	11
content analysis	11	31	trends	5	12
educational research	11	20	university rankings	5	2
journals	11	30	well-being	5	13
learning	11	30	ınclusion	5	6
research evaluation	11	20	India	5	10
research output	11	22	ındustry 4.0	5	11
universities	11	28	ınformation science	5	9
university	11	24	active learning	4	9
e-learning	10	28	bibliometric mapping	4	7
educational technology	10	23	bibliometric mapping analysis	4	3
physical education	10	23	bibliometrics analysis	4	6

Keyword	Occurrences	Total link strength	Keyword	Occurrences	Total link strength
social sciences	10	20	bibliometrix	4	4
sustainability	10	26	blended learning	4	3
teaching	10	27	citation impact	4	18
virtual reality	10	32	coronavirus	4	16
visualization	10	29	data visualization	4	7
augmented reality	9	37	digital literacy	4	12
co-word analysis	9	24	digital transformation	4	4
medical education	9	20	Ecuador	4	5
network analysis	9	19	educational innovation	4	6
research productivity	9	20	entrepreneurship	4	11
sustainable development	9	13	health	4	11
bibliometric review	8	16	health care	4	14
collaboration	8	12	journal citation reports	4	12
research trends	8	20	knowledge management	4	3
science	8	18	Latin America	4	10
h-index	7	15	library and information science	4	11
mathematics education	7	16	machine learning	4	4
scientific mapping	7	18	management	4	15
scientific productivity	7	11	nursing research	4	9
scientific research	7	13	performance analysis	4	9
technology	7	10	psychology	4	7
text mining	7	14	publication	4	5
ICT	7	18	research collaboration	4	14
ınnovation	7	12	research hotspots	4	6
co-citation analysis	6	19	sars-cov-2	4	9
gender	6	9	Saudi Arabia	4	12
google scholar	6	17	South Africa	4	11
h index	6	6	sport	4	13
health sciences	6	14	sustainable development goals	4	9
m-learning	6	21	trend	4	14
mobile learning	6	18	twitter	4	7
productivity	6	17	ındexing	4	9

According to the keyword analysis results, a large number of different clusters were identified; A total of 13 separate clusters were reached. When the map in Figure 2-A is examined, it can be seen that there are five basic

clusters (red, blue, green, purple and yellow) in this map, which consists of keywords related to "science education" and "bibliometrics", as well as clusters focused on smaller and relatively specific topics. is observed.The prominent term in the red cluster is “education” [Total Connection Strength (TBG)=164, Connections=71]. This finding is not surprising at all for our research. Pesta et al. (2018) stated in their study that “education” might attract relatively more research interest because the keyword is broadly multi-disciplinary. In the same cluster, after "education", terms such as "science mapping", "voswiever", "literature review", "review" draw attention. In this cluster, it is seen that different keywords that are similar to each other are preferred to describe the same concept.



A B

Figure 2. The Nexus of Article’ Keywords Clusters (A) and Trend of These Clusters (B)

The strongest node of the blue cluster is the keyword “bibliometrics” [Total Link Strength (TBG)=322, Links=109]. This finding is not surprising at all, as bibliometric studies were examined in this study. This term is followed by keywords such as "web of science," "scopus", "scientometrics". Web of science was traditionally the private and largest accessible database for bibliometric analysis, but since its introduction by Elsevier and its ease of accessibility at universities around the world, Scopus has become a major competitor of the Web of science for conducting such analysis (Echchakoui, 2020). As literature databases, Scopus and Web of Science differ in their scope, focus and the tools they provide. Scopus search provides the highest number of documents, followed by Web of Science (AlRyalat et al. 2019). In our research, it is seen that Web of Science has more connection power than scopus. The reason for this situation can be shown as the introduction of Scopus after web of science. As

another reason, it can be said that researchers prefer analysis with less documentation in their research.

The keyword with the most frequent node density in the green cluster is “citation analysis” [Total Connection Strength (TBG)=67, Connections=38]. This finding shows that the citation analysis method is frequently used in bibliometric research. Sun et al. (2012) stated that citation analysis and content analysis are commonly used methods in bibliometric analysis. Citation analysis is used to represent the analysis of bibliographic references that form part of the scientific communication apparatus (Nicolaisen, 2007). After “citation analysis”, the terms “research” and “publications” come to the fore.

In the purple cluster, "bibliometric indicators", "evaluation", "impact factor", "indexing", "journals", "physical education", "scientific journals", "scientific productivity", "social sciences", "sport", "university" It is seen that keywords such as “rankings”, “scientific collaboration” are included. The strongest node of this cluster is the keyword “bibliometric indicators” (TBG=43, Links=27). Bibliometric indicators are very important to researchers and organizations because these metrics are often used in funding decisions, appointments, and promotions of researchers. As more scientific discoveries occur and published research results are read and cited by other researchers, bibliometric indicators are becoming increasingly important (Durieux & Gevenois, 2010). This term is followed by keywords such as “social sciences”, “impact factor”, “physical education”. In this cluster, it can be said that the social sciences keyword contains various types of publications as the reason for the high ranking. Glänzel & Schoepflin (1999) stated that for social science research, it is published in a wide variety of publication types and covers more national issues than natural science research.

Yellow cluster “bibliometric”, “coronavirus”, “covid-19”, “dentistry”, “e-learning”, “medical education”, “online learning”, “public health”, “sars-cov-2”, “contains the keywords "science", "scientometric", "trend", "visualization". The strongest node of the yellow cluster is the “bibliometric” keyword [Total Link Strength (TBG)=115, Links=63]. In this cluster, it can be said that different keywords that are similar to each other are used to describe the same concept as the reason for the bibliometric keyword to be high. After the “Bibliometric” keyword, the covid 19 keyword attracts attention. Due to the pandemic, it can be said that the topic of Covid 19 is preferred by researchers because it is up-to-date.

The study's findings were subjected to analysis in two distinct dimensions. The second facet of the analysis focuses on the temporal trend. In light of the time trend revealed by the keyword analysis, recent research on bibliometric articles in science education notably features terms such as "coronavirus," "covid-19," "sars-cov-2," and similar expressions (Figure 2-B). This observation could signify the emergence of new research interests among scholars in the field of science education. It was determined that the source of pneumonia cases of unknown origin, which was reported from the city of Wuhan, China on 31 December 2019, is coronaviruses, a large family of viruses that cause serious infections ranging from mild infections to severe acute respiratory syndromes. The disease originating from this family, a new type of coronavirus that has not been detected before, has been defined as Covid-19 (Akyavuz and Çakın, 2020). The virus has affected the whole world in every field and has caused changes in the field of education. Related to the subject, Kırmızıgül (2020) stated that Covid-19, which affected the whole world, caused disruptions in the field of education as well as in different fields, and that it was inevitable

in the education process and practices as a result of the changes that occurred in the digital world and learning environments before and after the Covid-19 epidemic. indicated that changes had occurred.

Term Analysis: Most Common Terms in the Article

To determine the most frequently used terms in the obtained documents, 20 documents were used as the minimum number of occurrences of a term. In total, out of 16,972 terms, 263 met the specified threshold. The 263 most relevant terms were selected by calculating a relevance score for each term. The default selection was to contain 60% of the most relevant terms. Finally, 159 terms were selected for further analysis of the visualization and networks between terms (see Table 2).

Table 2. Examining the Publications in Terms of Terms

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
citation	229	0.3337	word	43	0.9123
university	201	0.3766	case	42	13.122
technology	165	0.4895	research field	42	0.8506
keyword	162	0.6924	visualization	42	11.394
scientific production	119	0.3548	bibliometric data	41	0.8711
level	115	0.4579	comparison	40	23.472
learning	113	11.665	gap	40	0.6204
process	107	0.3975	impact factor	40	21.691
evolution	102	0.4029	opportunity	40	0.5229
indicator	97	1.378	scientific literature	40	0.3824
theme	93	11.663	list	39	10.335
bibliometric indicator	91	13.432	united state	38	0.9274
performance	90	12.322	relation	37	0.5536
quality	88	0.4123	basis	36	0.3953
map	85	0.7115	content analysis	36	0.9108
perspective	85	0.3363	highest number	36	11.848
united states	82	0.8926	science core collection	36	13.386
methodology	79	0.3012	top	36	0.5842
policy	76	0.1674	total number	36	14.724
index	74	20.196	international collaboration	35	0.8434
group	73	0.4206	variable	35	0.9409
factor	72	0.4865	vosviewer software	35	15.538
assessment	71	0.9594	abstract	34	0.7668

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
productivity	71	13.593	brazil	34	0.6492
structure	71	0.6578	COVID	34	27.333
vosviewer	71	15.792	productive author	34	0.9894
mapping	70	0.7367	subject area	34	0.995
attention	69	0.6838	Canada	33	1.308
change	69	0.4393	form	33	0.4244
evaluation	69	18.618	scope	33	0.6803
output	69	15.898	united kingdom	33	13.567
health	68	0.4285	Australia	32	10.417
china	65	12.261	google scholar	32	14.062
USA	65	0.5654	higher education institution	32	0.9299
recent year	63	0.5476	journal article	32	0.5828
teaching	63	0.8634	medical education	32	0.8731
cluster	60	0.8981	ministry	32	22.725
concept	60	0.872	scientific output	32	12.308
environment	59	0.4757	scientist	32	15.308
medicine	59	0.5458	dissemination	31	0.9037
implication	58	0.4482	history	31	0.57
training	57	0.2477	originality value	31	15.574
language	56	0.6397	systematic review	30	10.109
difference	55	24.137	academic	29	11.019
region	55	0.4831	citespace	29	21.881
model	54	0.4784	design methodology approach	29	16.209
research output	54	21.198	peer	29	0.3781
title	53	0.5651	business	28	0.8282
way	53	0.3805	gender	28	0.6321
citation analysis	52	10.391	scientific productivity	28	10.515
insight	52	0.5948	limitation	27	0.6596
research topic	52	10.701	nation	27	0.7467
degree	51	12.097	research productivity	27	42.059
problem	51	0.2584	scientific community	27	0.6663
resource	51	0.1594	nursing	26	18.605

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
aspect	50	0.4209	scientific journal	26	23.569
sample	50	0.3707	sustainability	26	12.226
understanding	50	0.6541	ıntroduction	26	0.5349
value	50	0.9902	average	25	27.486
h index	49	26.793	bibliometric technique	25	0.721
ranking	48	25.289	end	25	0.444
research trend	48	18.344	government	25	0.889
set	48	0.2307	quantity	25	14.457
skill	48	0.7304	scientific article	25	0.7862
society	48	0.3719	effectiveness	24	0.5544
psychology	47	0.5405	origin	24	0.5362
challenge	46	0.3701	pandemic	24	33.143
educational research	45	0.2915	India	24	1.765
English	45	0.6057	individual	23	10.993
line	45	0.9062	prolific author	23	0.7204
point	45	0.5214	bibliometric review	22	15.718
computer science	44	0.3422	future study	22	12.339
engineering	44	0.4938	January	22	11.839
innovation	44	0.3909	research hotspot	22	22.922
library	44	0.5975	sustainable development	22	12.896
future research	43	10.174	economic	21	10.385
influence	43	0.6125	health science	21	1.723
school	43	0.3279	physical education	21	13.077
Spain	43	0.3688	educational technology	20	2.201
teacher	43	12.663			

According to these findings, “citation” (f=229) is among the most common terms in studies. The words “university” (f=201), “technology” (f=165) are also among the common terms used in research. However, since it is the closeness/relationship that interests us here, the highest relevance scores include “research productivity” (R.Sc: 42.059), “pandemic” (R.Sc: 33.143); h index (R.Sc: 26.793); “average” (R.Sc: 27.486) are included (Table.2). In term analysis, 4 clusters were identified (see Figure 3-A). Cluster-1 (red) consists of 63 terms. The most prominent are the terms “citation”, “university”, “bibliometric indicator”, “group”, “level”. Cluster-2 (green) consists of 47 terms, most notably the terms “key word”, “United States”, “vosviewer”, “citation analysis”, “health”, “attention”. Cluster-3 (blue) consists of 32 terms, most notably the terms "technology", "scientific production", "learning", "environment", "evolution", "teaching level". Cluster-4 (yellow) consists of 17 terms.

The most prominent are the terms “structure”, “originality value”, “cluster”. In addition, in the temporal network analysis graph shown in Figure 3B, the yellow color shows the terms used in the articles made in recent years.

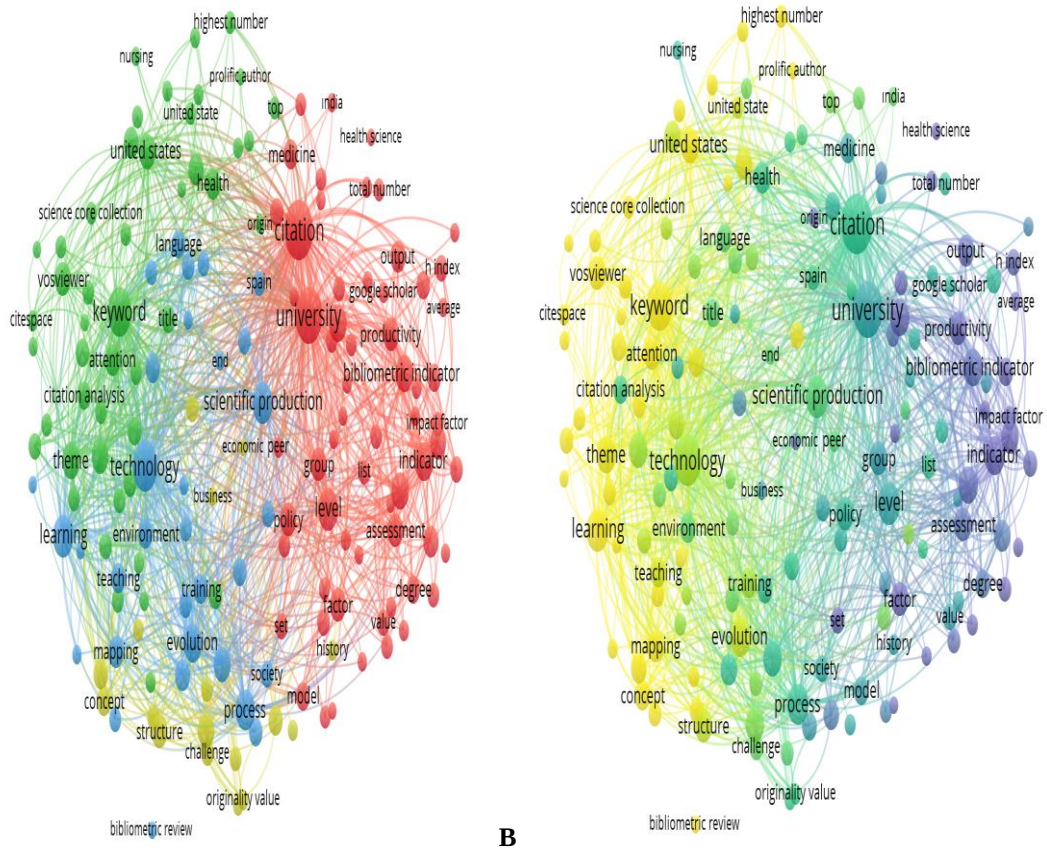


Figure. 3. The Nexus of Term Analysis Clusters (A) and Trend of These Clusters (B)

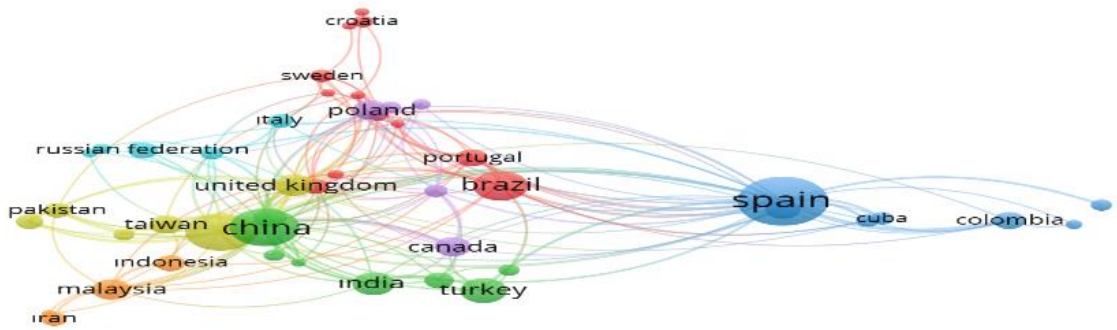
Countries Analysis: Most Published Countries of the Article

We also conducted a country analysis to reveal the spatial distribution of the reports. According to the documents obtained, 101 countries have published documents on this subject. However, we set a country's minimum number of documents at five and identified 47 countries that met this threshold (see Table 3). For each, we calculated the total strength of co-authorship connections with other countries. We also considered the total citations of documents by country. Countries with the highest total connectivity strength were selected for subsequent analysis.

Table 3. Examining the Publications in Terms of Countries

			Total link				Total link
Country	**Documents**	**Citations**	**strength**	**Country**	**Documents**	**Citations**	**strength**
Spain	167	2552	72	Netherlands	12	315	14
United States	100	1327	55	Cuba	12	65	7
China	100	601	46	Mexico	11	161	10
Brazil	60	589	25	France	11	149	13
Turkey	45	463	12	Viet Nam	10	55	5

Country	Documents	Citations	Total link strength	Country	Documents	Citations	Total link strength
India	36	157	14	Kazakhstan	10	168	3
United Kingdom	35	832	46	Japan	10	253	16
Malaysia	29	142	19	Hong Kong	9	149	15
Poland	27	229	19	Ecuador	9	31	3
Chile	27	155	24	Denmark	9	103	4
Canada	27	301	23	Croatia	9	32	4
Australia	25	350	32	Romania	8	58	3
Taiwan	23	297	13	Austria	8	46	10
Colombia	22	255	14	Switzerland	7	322	9
Portugal	20	165	22	Peru	7	10	2
Indonesia	18	41	6	South Korea	6	12	3
South Africa	18	196	13	Thailand	5	40	9
Russian Federation	18	117	8	Slovenia	5	31	1
Pakistan	17	80	14	Serbia	5	56	10
Germany	17	435	16	Nigeria	5	19	2
Saudi Arabia	15	62	15	Greece	5	78	7
Italy	13	264	7	Finland	5	62	7
Iran	13	77	2	Belgium	5	88	2
Sweden	12	159	10				



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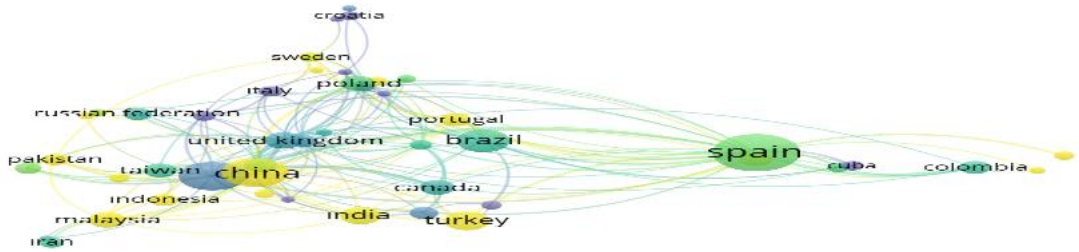


B

Figure. 4. The Nexus of Citation among the Countries (A) and Trend of These Clusters (B)

The citation network covers 47 countries. Countries are represented by nodes. A greater number of nodes indicates a greater number of publications. Connectivity refers to the lines between countries. Accordingly, in this study, it is striking that Spain has more important nodes with 2552 citations (Table 3). It is seen that United states ranks second with 1327 citations. These countries are followed by China with 601, Brazil with 589 citations. Overall, Spain tops the list with 167 publications in the global publication share of 47 countries, followed by United States (100 publications), China (100 publications), Brazil (60 publications) and Turkey (45 publications) (Table 3). Seven clusters have been identified for citations. Twelve countries, including Belgium, Brazil, Croatia, Finland, Germany, Greece, Japan, Portugal, Serbia, Slovenia, Sweden, Switzerland, were placed in cluster-1 (Red). Cluster-2 (green) Australia, China, Denmark, India, South Africa, Turkey, Vietnam; Cluster-3 (blue) Chile, Colombia, Cuba, Ecuador, Mexico, Peru, Spain; Cluster-4 (yellow) Kazakhstan, Pakistan, Saudi Arabia, Taiwan, United Kingdom, United States; Cluster-5 (purple) Australia, Netherlands, Canada, Hong kong, Polands; Cluster-6 (turquoise) France, Italy, Romania, Russian federation, South Korea; Cluster-7 (orange) includes Indonesia, Iran, Malaysia, Nigeria (Figure 4A). In addition, in the temporal network analysis graph shown in Figure 4B, the yellow color shows the trending countries working in the recent articles. According to this survey, Spain was the most productive with 167 publications. It follows Spain with 100 broadcasts from United States. This situation is quite remarkable for our research. Although the USA is one of the leading countries in the field of science education (Demir & Selvi, 2018; Yurdakul & Bozdoğan, 2022), it is seen that it ranks second.

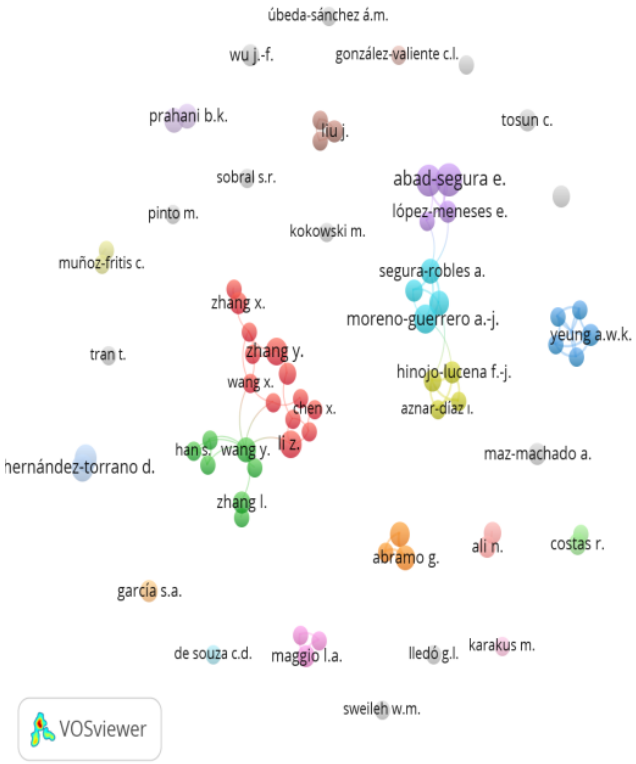
Author Citation Analysis: Most Productive Authors in the Article

In order to reveal the relationship between the authors with a clearer analysis, authors who contributed at least three articles were selected. Out of a total of 2481 authors, 72 meet the relevant threshold.

Table 4. Examination of Publications in Terms of Authors

Author	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
Abad-Segura E.	9	257	12	Chen J.	3	16	4
González-Zamar M.-D.	8	250	12	Chen X.	3	35	2
Moreno-Guerrero A.-J.	7	64	7	Chen Y.	3	3	3
Hernández-Torrano D.	6	110	1	Chen Z.	3	26	3
Ho Y.-S.	6	177	1	Cicero T.	3	112	6
Li Z.	6	40	3	Costello J.A.	3	8	5
Zhang Y.	6	139	4	Cáceres-Reche M.-P.	3	69	9
Abramo G.	5	148	8	De Souza C.D.	3	3	0
D'angelo C.A.	5	148	8	Duan Z.	3	20	5

Author	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
López-Belmonte J.	5	45	9	Eibensteiner F.	3	15	12
Prahani B.K.	5	5	5	Frank J.R.	3	15	5
Segura-Robles A.	5	33	10	González-Valiente C.L.	3	9	0
Suprapto N.	5	5	5	Han S.	3	19	5
Wang Y.	5	17	8	Huang Y.	3	56	5
Ali N.	4	22	3	Karakus M.	3	37	0
Costas R.	4	94	1	Kletecka-Pulker M.	3	15	12
García S.A.	4	20	0	Kokowski M.	3	13	0
Hinojo-Lucena F.-J.	4	91	10	Larivière V.	3	110	1
Liu J.	4	7	4	Lledó G.L.	3	16	0
López-Meneses E.	4	64	9	Muñoz-Fritis C.	3	0	3
Maggio L.A.	4	15	6	Pedraja-Rejas L.	3	0	3
Maz-Machado A.	4	9	0	Pinto M.	3	66	0
Parra-González M.E.	4	22	6	Porter A.L.	3	60	4
Pérez-Gutiérrez M.	4	9	0	Shubina I.	3	7	0
Romero-Rodríguez J.-M.	4	90	10	Sobral S.R.	3	21	0
Shoaib M.	4	26	3	Sweileh W.M.	3	26	0
Tosun C.	4	2	0	Tran T.	3	15	0
Wang P.	4	16	3	Vázquez-Cano E.	3	47	5
Wu J.-F.	4	2	0	Wang J.	3	7	1
Yeung A.W.K.	4	110	12	Wang L.	3	11	1
Zhang L.	4	7	2	Wang S.	3	45	2
Zhang X.	4	1	2	Wang X.	3	26	4
Atanasov A.G.	3	15	12	Willschke H.	3	15	12
Aznar-Díaz I.	3	69	9	Zhang Q.	3	4	4
Chen D.	3	11	1	Zhu R.	3	19	5
Chen G.	3	23	3	Úbeda-Sánchez Á.M.	3	4	0



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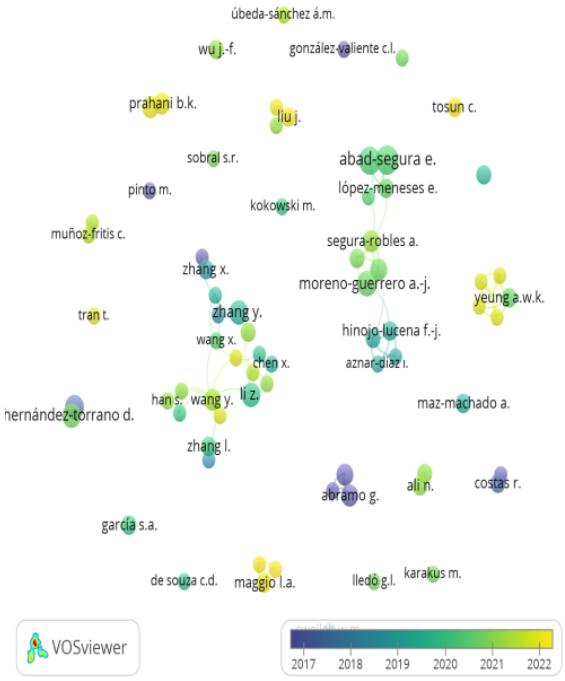


B

Figure 6. The Most Cited Authors (Co-Citation Analysis) (A) and Trend of These Clusters (B)

Identifying the most prolific authors is one of the critical points of bibliometric research. In this research, Abad-Segura E. is the author who has done the most work on this subject with 9 publications. In second place is González-Zamar M.D., who has 8 publications on this subject. (Figure.6-A). In addition, in the temporal network

analysis graph shown in (Figure.6-B), the yellow color shows the authors who have published and collaborated in recent years.

Lotka's law, which is widely used in bibliometric analysis, was evaluated to examine the productivity of authors. Lotka's Law suggests that the number of authors in a field follows a certain pattern. For example, two authors represent 1/4 of an author, three authors represent 1/9 of an author, and the number of people writing n articles is around 1/rf of an author, while the ratio of people writing articles is generally around 1/rf of an author. It is suggested that it is around 60% (Lotka, 1926; Yılmaz, 2006, p.63). The findings obtained in this study show that the author distribution of the articles written does not comply with Lotka's Law.Lotka's law and the rate of working authors were created by the authors through the R bibliometrix program (Figure 7). In addition, the impact rate of the most productive authors on this topic is given through the bibliometrix program (Table 5). Table 5 shows the total number of citations of the authors (TC), the number of publications they have made (NP), and when they started the first publication (PY). According to these data, it is quite remarkable that abad segura e is the most prolific writer on this subject, even though it started in 2020.

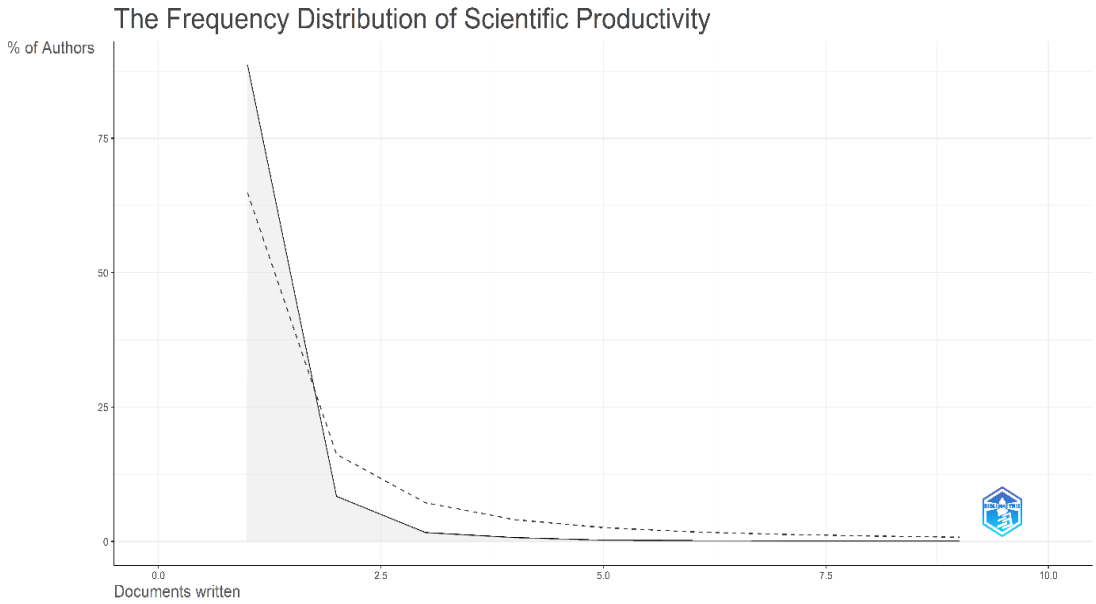


Figure 7. Lotka's Law and the Rate of Authors

Table 5. Author Local Impact

Authors	h_index	g_index	m_index	TC	NP	PY_start
ABAD-SEGURA E	7	9	2,333	257	9	2020
GONZÁLEZ-ZAMAR M-D	7	8	2,333	250	8	2020
ABRAMO G	4	5	0,333	148	5	2011
ALI N	4	4	2	22	4	2021
D'ANGELO CA	4	5	0,333	148	5	2011
HERNÁNDEZ-TORRANO D	4	6	1,333	110	6	2020
MORENO-GUERRERO A-J	4	7	1,333	64	7	2020

Authors	h_index	g_index	m_index	TC	NP	PY_start
SHOAIB M	4	4	2	26	4	2021
ATANASOV AG	3	3	1,5	15	3	2021
CICERO T	3	3	0,25	112	3	2011

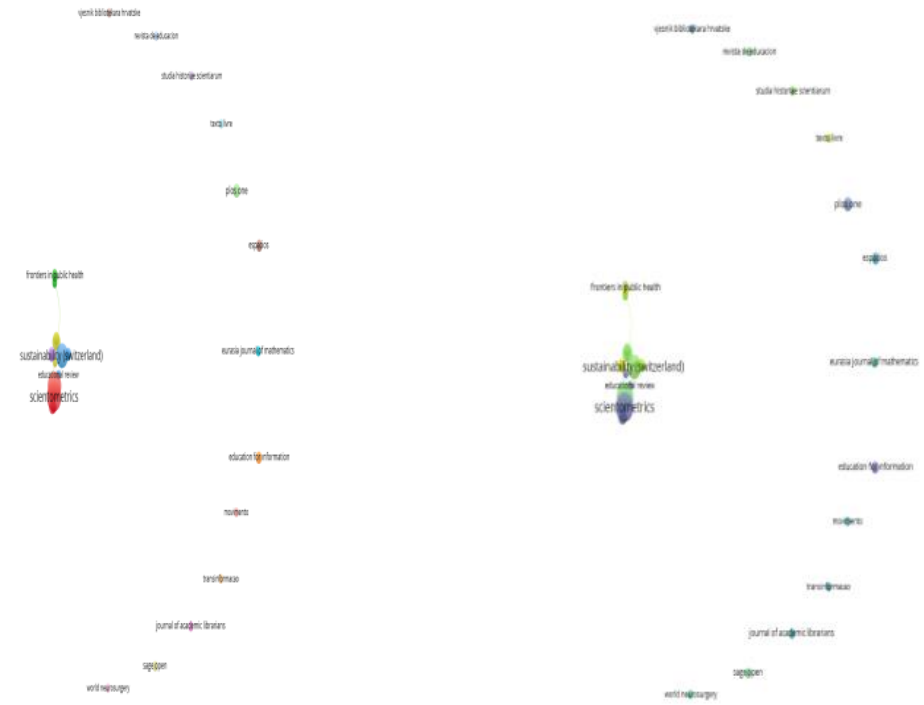
Journal Analysis: Most popular Journals in the Article

For the purpose of the study, journals with at least four publications in the relevant field were examined to determine the most preferred journals. Out of a total of 518 journals, 32 journals that met this criterion were identified (see Table 6). Accordingly, “Scientometrics” (35 documents, 544 citations), “Sustainability (Switzerland)” (25 documents, 499 citations), “Computers and Education” (4 documents,439 citations), “Journal of the American Society for Information Science and Technology” (4 documents, 298 citations) were the most cited journals in the studies (see Table 6). When the citations received by the publications in the mentioned journals are examined, it is seen that a few journals come to the fore. For example, "Computers and Education" (4 documents,439 citations), although it is low in terms of publications, it is seen that it is high in terms of citations. There is an interesting situation regarding the citations of the “Library Philosophy and Practice Journal”. This journal, which publishes many articles (31) has a very low of citations per article (69). The same situation is observed in some other journals (see Table 6). For future science education researchers, this can provide useful information regarding journal selection. It is also seen that the journal “Scientometrics” has the highest link strength (16) among all journals (see Table 6).

Table.6. Most Popular Journals in the Article

Source	Documents	Citations	Total Link Strength
Scientometrics	35	544	16
Library Philosophy and Practice	31	69	9
Sustainability (Switzerland)	25	499	6
Education Sciences	12	170	9
Education and Information Technologies	9	27	1
Journal of Informetrics	8	248	5
Plos One	8	237	0
Higher Education	7	216	3
Ieee Access	7	114	1
International Journal of Emerging Technologies in Learning	7	16	1
Education for Information	6	22	0
Espacios	6	9	0
Frontiers in Psychology	6	46	1
Frontiers in Public Health	6	42	2
Eurasia Journal of Mathematics, Science And Technology	5	87	2

Source	Documents	Citations	Total Link Strength
Education			
Journal of Academic Librarianship	5	66	0
Sage Open	5	22	0
Computers and Education	4	439	4
Educational Review	4	82	3
Journal of Advanced Nursing	4	63	3
Journal of Nursing Management	4	13	1
Journal of The American Society For Information Science And Technology	4	298	2
Movimento	4	13	0
Participatory Educational Research	4	9	2
Revista De Educacion	4	12	0
Studia Historiae Scientiarum	4	13	0
Technological Forecasting And Social Change	4	66	1
Texto Livre	4	1	0
Transinformacao	4	24	0
Vjesnik Bibliotekara Hrvatske	4	3	0
World Neurosurgery	4	8	0
International Journal of Interactive Mobile Technologies	4	53	2



A B

Figure 8. The Most Cited Journals Clusters (Co-Citation Analysis) (A) and Trend of These Clusters (B)

According to the VOSviewer map, it is seen that the most cited journals are grouped around 18 different clusters (Figure 8-A), while in Figure 8-B, journals such as "Education and Information Technologies", "Frontiers in Psychology", "Texto Livre" stand out. is observed. According to time trend analysis, it has been determined that these journals have been preferred by researchers in recent years. 18 different clusters were identified in the journal analysis. Cluster-1 (5 items), Cluster-2 (4 items), Cluster-3 (4 items), Cluster-4 (3 items), Cluster-5 (2 items), Cluster-6 (2 items) and the remaining sets contain 1 item. Links are observed between some clusters. This shows that a node can have many connections with other nodes and thus occupy a central position in the cluster. To evaluate the advantageous position of a node, it is important to consider the number of connections as well as the proximity and betweenness criteria. Examining the social network shows that the relationships mostly focus on journals such as "Scientometrics" and "Sustainability (Switzerland)". This indicates that these journals have an important position in the network.

Conclusion

The main purpose of this study is to explain the content analysis and trends of studies on bibliometric articles in the field of science education. In this context, the following data were obtained through the bibliometric network analysis carried out in the Scopus database, which contains 846 articles related to science education. Between 1974 and 2023, which was determined as the time period in the research, the year in which the most studies were published is seen as 2022. The most frequently used keywords in publications are "education", "research", "bibliometrics", "citation analysis". Among the high relevance scores are the terms "research productivity", "pandemic", h index ", "average". Another result of the research is abad-segura e., which has 9 publications on the subject. is the most productive writer. In addition, Lotka's law was used to measure the productivity of writers, but it was found that it did not comply with this research. Accordingly, among the most cited sources in the studies were "Journal of Research in Science Teaching", "Computers and Education", "International Journal of Technology and Design Education". It is noteworthy that in this study, Spain has more important nodes with 2552 references. The most cited journals in the studies were "Scientometrics", "Sustainability (Switzerland)", "Computers and Education", "Journal of The American Society for Information Science and Technology".

Recommendations

We believe that the results of this study are important for future developments in science education. The research provides insight into topics in relevant disciplines. Additionally, more detailed bibliometric studies can be conducted in different areas of education by taking into account the macro data presented in this research. Bibliometric studies are important for researchers to closely follow the studies and developments in this field. For this reason, it directs the areas of interest of new research as a method and it can be recommended to conduct bibliometric studies in different fields.

Moving from the findings of the present study, some suggestions could be made for further research in the field:

- It is recommended to continue research to give importance to the determination of bibliometric studies in science education.

- According to the keyword analysis, the most relevant keywords related to bibliometric studies in science education include "education", "research", "bibliometrics", "citation analysis", "bibliometric indicators". It is important to focus on research that includes other keywords that include bibliometric studies in science education.
- According to the term analysis, the most frequently used terms in bibliometric studies in science education include "research productivity", "pandemic", "h index" and "average". Attention should also be paid to studies that include other variables related to bibliometric studies in science education.
- The research is limited to published articles from bibliometric studies in science education. Therefore, researchers can conduct more comprehensive bibliometric analyzes using various keywords to understand the basic studies in their chosen research field and benefit from these publications.
- The study is limited to research in the Scopus database. Other indices can also be used in future studies and thus a broader perspective can be obtained.
- The type of publication included in the sample of the study is limited to articles. Other publication types such as thesis, conference proceedings, or books could use in the analyses.
- Further studies could be conducted using different limitations when searching for the articles.

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Author Information

Meryem Konu Kadirhanoğulları
https://orcid.org/0000-0001-7359-7061
Kafkas University
Turkey
Contact e-mail: *meryem_6647@hotmail.com*

Esra Özay Köse
https://orcid.org/0000-0001-9085-7478
Ataturk University
Turkey