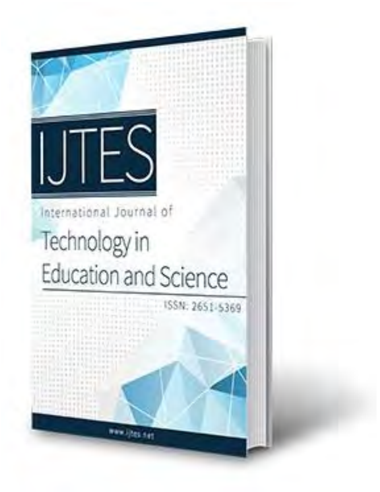

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Bibliometric Analysis: Technology Studies in Science Education

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Bibliometric Analysis: Technology Studies in Science Education

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Abstract

It is thought that the results of a study examining the articles published in peer-reviewed journals on technology in science education in terms of many criteria will provide important information to researchers. For this purpose, bibliometric network analysis was chosen as a method. The purpose of choosing this research method is to clearly summarize the relationship between science education and technology in order to identify technology in science education. In order to answer the research questions, bibliometric data consisting of 8511 articles in the Scopus database were evaluated using the bibliographic data obtained with the VOSviewer program. In addition, Pareto Law, Price Law, Lotka Law were used within the scope of citation analysis in the research. The results obtained from the research are presented.

Introduction

Technological advances are also effective in the field of education and training, as in all areas of life. From the second half of the 20th century, understanding the mutual interaction between science, technology and society in the field of education has gained importance. The rapid development in every field and the increase in investments in technology in the field of education forced educators to develop the education system. The technology that develops in line with the needs of the society must be understood by the individuals who make up the society. Since there is a three-way relationship between technology and education: raising technical manpower, benefiting from the opportunities offered by technology in education, and raising individuals with the skills to adapt to the technological environment, scientific developments have necessitated bringing a technological dimension to education. Even when the elements such as theoretical principles, manpower, method-technique, environment, target, student, learning situations and evaluation in educational technology are considered independently of each other, it becomes clear how important educational technology is in educational practices. In other words, educational technology covers a wide area from educational theory to its application and evaluation, in short, every aspect of educational activities (Özgan, 2010). Despite the increase in access to technology in educational institutions aiming to raise successful individuals, it has been observed that the expected increase in teaching practices has not been achieved, and therefore, the necessity of restructuring the education-training process according to technological developments has emerged (Fidan, 2012).

Along with technology, it is of great importance that science is best understood by all individuals in the society. In this context, in science education and scientific literacy; it has been seen that new regulations have been introduced to eliminate the problems related to health, natural environment, communication, energy resources and food resources (NRC, 1996; Bacanak, 2002). The studies carried out within the scope of these new regulations have also changed the special aims and science-technology concepts in science education (Hurd, 1998). In this context, it is stated in many sources that the task of developing science and technology literacy, which is accepted as one of the most important goals of science education, is to understand technology and the interaction of technology with science and society (AAAS, 1993; NRC, 1996; Hurd, 1998; Bybee, 1999; Murphy et al., 2001, Bacanak, 2002).

An individual who is science and technology literate is an individual who understands the relationship between these two concepts as well as their relations with society. Science and technology have many aspects in common. As a matter of fact, similar skills and mental habits are used in both scientific research and technological design processes. The most important feature that distinguishes science and technology from each other is that their purposes are different. The aim of science is to try to explain the natural world by understanding; the purpose of technology is to make changes in the natural world to meet people's wishes and needs (MEB, 2005). In studies on science education and technology; it has been revealed that technology supports the development of some science skills, saves time, and improves students' critical and creative thinking skills (Jimoyiannis & Komis, 2001; Goldworthy, 2000).

The fact that technology integration in education took place at a significant level in science classes dates back to the 20th century (Kartal, 2017). With the use of film, picture, slide, projection, radio, video recorder, computer and internet in schools, technology integration has been achieved in science lessons, and it has been determined that teaching by integrating technology has positive effects on student achievement compared to other teaching methods (Köse, Ayas, & Taş, 2003; Yenice, Sümer, Oktaylar and Erbil, 2003). Technology-assisted education has many advantages for teachers as well as students. In the process of reaching and preparing curricula and activities, computers provide important conveniences to teachers (Engin, Tösten, & Kaya, 2010). Pre-planned and prepared educational computer programs in order to increase the efficiency of the students in the lessons have an effective role in attracting the attention of the students to the lesson. The presentations, visuals and documentaries used to increase students' focus on the lesson are prepared much more easily and in a short time thanks to the computer, and they make a great contribution in gathering and relating related subjects in different fields (mathematics, social, science, etc.) within the same framework (Akçay et al. 2005).

In recent years, many studies have been carried out on the use of technology in science education, these studies contain many sub-dimensions such as the subjects examined, their distribution by years, keywords, participants, countries of participants, publishing institutions. This research was conducted specifically to analyze the content of research on the use of technology in science education. In particular, questioning the qualitative and quantitative information of scientific research on science education is of great importance in terms of revealing the quality of these studies, and also contains important and explanatory information for other researchers related to that field (Bacanak et al., 2011). In addition, studies and published scientific articles guide new researchers about what previous research is (Henson, 2001; Tsai & Wen, 2005). In other words, it is important to determine the trends by examining and arranging the researches in the field of science education at regular intervals in terms of shedding light on the scientists who want to work in the related field (Çiltaş et al., 2012). This makes it necessary to examine these studies with content analysis (Gül and Köse, 2018). With content analysis studies, science educators will be aware of the trends in the national and international literature related to their fields, avoid re-examining the frequently studied topics and carry out new studies that can contribute to the relevant literature (Çalık, Ünal, 2009).

Bibliometric analysis is a popular and rigorous method used to research and analyze large volumes of scientific data. While it enables us to reveal the evolutionary nuances of a particular field, it enables us to shed light on the emerging fields in that field (Donthu et al., 2021). Bibliometric analysis is used to quantitatively analyze the relationship between journals, to reveal the knowledge status and research trend of the discovery area by reviewing a large number of academic literature, and to describe the cooperation between countries, the citation relationship between authors, and the knowledge structure of the research area (He et al., 2020). Scholars have suggested that the bibliometric technique is an interdisciplinary method that enables effective mapping of aspects and themes addressed during the development of a research field (Khanra et al., 2020, 2021; Liao et al., 2018; Martínez-L´opez et al., 2018; Tandon et al., 2021).

The objective of this study is to reveal the content analysis and trends of studies on technology in science education. In this context, documents about technology in science education scanned in the Scopus database were subjected to bibliometric network analysis. The bibliometric analysis used in the research was conducted to find out the answers to the questions given below.

1) What are the distributions of studies on technology in science education according to the years?
2) What are the distributions of key words related to technology in science education?
3) What are the distribution of terms that are frequently used in studies on technology in science education?
4) What are the distribution of the countries where studies on technology in science education?
5) What are the distributions of the author citation in studies on technology in science education?
6) What are the distributions of the sources where studies on technology in science education?

Method

Data Collection Process

Scopus database was used to identify researches related to technology in science education. The Scopus database combines the best features of PubMed and Web of Science into one comprehensive resource. Likewise, Scopus is the only database that combines a comprehensive, expertly curated abstract and citation database with enriched data and cross-referenced scholarly literature from multiple disciplines (Abdullah,2022). Data are from the online version of the Scopus database dated January 13, 2023. All record with the phrase “science education and technology” in “article title, abstract, keywords” were accessed. Accordingly, 54,533 documents containing the word “science education and technology” were found. However, since not all of these publications are related science education and technology, the "Social Sciences" section was selected from the "Subject Area" section of Scopus. Afterwards, the article was selected as the document type and only the articles in 2013 and 2023 were included in the research. As a result, between 2013 and 2023, 8511 publications on science education and technology were discovered. No language restrictions are taken into account.

Analysis of Data

Bibliometric analysis is employed to get quantitative analysis, gaining the distribution pattern of articles related to a topic, field, author, institution, or country by developing objective criteria used to select, review, and track published research (Nandiyanto et al.,2023).The reason why bibliometric network analysis was preferred as the method in our study is that the holistic and temporal plane, which is difficult to understand due to the continuous cumulative development of the literature on technology research in science education, will thus be summarized in an understandable way. Another reason for using bibliometric network analysis in research is to determine the relations between certain topics, journals, authors, institutions or countries by visualizing scientific research (Van Eck and Waltman, 2010: 523-538). There are many tools available for bibliometric analysis, such as CiteSpace, VOSviewer, and HistCite, which provide visual views based on user interfaces, the Bibliometrix package in R, which is based on code commands, and Pajek and Gephi, which focus on constructing complicated network analysis. Among them, Visualization of Similarities viewer (VOS) is becoming increasingly popular in bibliometric studies, with its outstanding visualization capabilities and usability to load and export information from many sources for creating maps based on network data, and to visualize and explore these maps (Van Eck and Waltman, 2010; Moral-Muñoz et al.,2020; Jia, & Mustafa, 2023). VOSviewer is a software tool used to create and visualize bibliometric networks (Van Eck and Waltman, 2017). In this research, the VOSviewer v.1.61 (Centre for Science and Technology Studies) program was used for the bibliometric analysis of 8511 publications, and publication years, country rankings, etc. were used. The findings obtained with various variables were interpreted according to frequency, relationality, clustering and time analysis. Frequency is the frequency of the text and bibliometric data that make up the analysis units in the network maps obtained as a result of the assumptions. This principle is simply how many times a unit is used in the analysis. Relationality, on the other hand, refers to the level of relationality between the bibliometric data determined by frequency, that is, the state of being together. Accordingly, units with high relevance were transferred to the network map by the program, while units with low relevance were excluded (Al et al., 2012; Tindall & Wellman, 2001). In addition, Pareto Law, Price Law, Lotka Law were used within the scope of citation analysis in the research. The most frequently applied laws within the scope of bibliometric laws; Bradford's Law, Pareto's Law, Price's Law, Lotka's Law. (Gökkurt, 1994, p. 29).

Findings

Distribution of Publications by Years

In Figure 1, when the trend of 8511 publications related to technology in science education between 2013 and 2023 is examined, it is seen that there are fluctuations in the number of publications according to years, but the studies are increasing gradually. It peaked in 2022 with a total of 1416 studies. Since 2023 has not been completed, it can be thought that this number will increase even more. The increase in the number of documents devoted to technology in science education can be explained as proof that this subject has a necessary and important place among academicians.

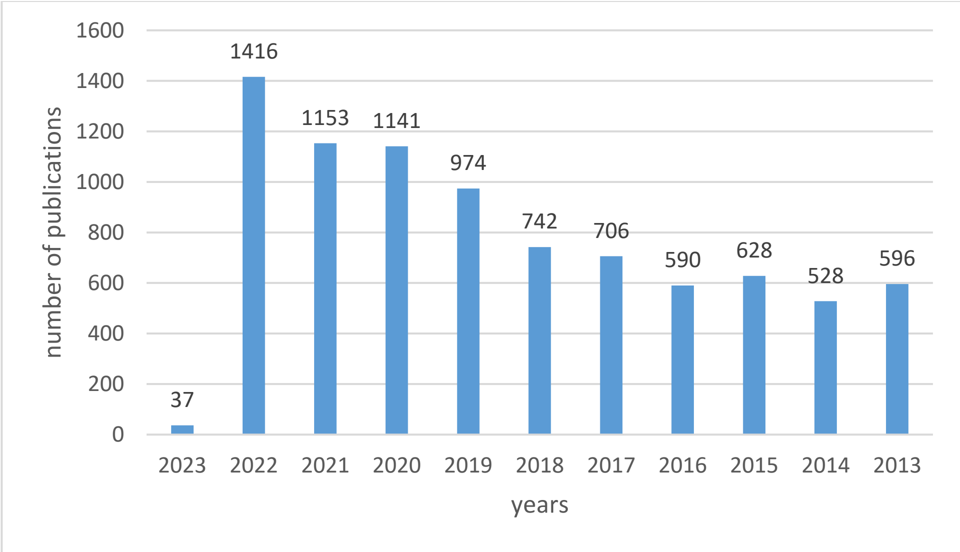


Figure 1. The Distribution of the Number of publications with Bibliometric Analysis by Years

Keyword Analysis: **Most Common Keywords in the Publications**

Keyword is of the critical points of researches. In this regard, the keyword analysis was carried out and the core keywords were revealed. Regarding analysis, it was considered 20 keywords as the minimum occurrences of a keyword. Out of the 18206 keywords, 191 met the threshold. For each keyword of the 191 keywords, the total strength of the co-occurrence links with other keywords were calculated. For that reason, the keywords with the greatest total link strength were selected for further network analysis (see Table1). Example visualizations created with VOSviewer for keyword analysis are shown in Figure 2.

Table 1. The most common keywords retrieved from the documents

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
stem	622	926	case study	32	42
higher education	564	817	meta-analysis	32	55
education	447	736	qualitative research	32	50
science education	446	494	science teaching	32	36
stem education	424	445	women	32	42
technology	379	731	ınformal learning	32	37
science	247	525	policy	31	54
gender	214	359	technology integration	31	42
educational technology	164	257	digital technologies	30	34
engineering education	137	164	digital technology	30	46
curriculum	119	192	race	30	71
teacher education	117	154	undergraduate	30	57

Keyword	**Occurrences**	**Total Link Strength**	**Keyword**	**Occurrences**	**Total Link Strength**
e-learning	115	157	bibliometric analysis	29	36
professional development	110	175	online education	29	56
engineering	107	289	training	29	61
secondary education	101	183	ınformation and communication technologies	29	48
learning	98	186	academic achievement	28	34
ICT	94	157	knowledge	28	59
technology education	92	99	pedagogical issues	28	48
covıd-19	91	163	social networks	28	39
motivation	91	130	technology-enhanced learning	28	44
mobile learning	89	137	design	27	54
pedagogy	86	154	high school/ıntroductory chemistry	27	28
active learning	85	130	nature of science	27	32
augmented reality	83	145	physics	27	47
online learning	83	150	science and technology studies	27	15
mathematics	82	235	teacher professional development	27	34
self-efficacy	79	122	university students	27	36
virtual reality	77	117	climate change	26	23
assessment	75	106	constructivism	26	46
computational thinking	74	113	development	26	56
sustainability	73	109	gender gap	26	36
steam	70	114	library and information science	26	22
teaching	67	145	ınteractive learning environments	26	42

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
computer science education	65	82	curriculum development	25	28
blended learning	64	95	digital competence	25	56
medical education	62	69	game-based learning	25	58
distance education	60	90	problem solving	25	43
creativity	59	89	secondary school	25	40
students	59	130	simulation	25	32
ınnovation	59	98	ınquiry-based learning	25	40
university	58	100	ınternet	25	33
computer science	57	87	experiential learning	24	22
mathematics education	57	81	perception	24	39
science and technology	57	67	retention	24	42
project-based learning	56	95	science teachers	24	29
sustainable development	53	71	technology acceptance model	24	34
artificial intelligence	52	67	upper-division undergraduate	24	42
teacher training	52	79	academic libraries	23	31
equity	51	96	achievement	23	56
diversity	50	73	digital literacy	23	32
bibliometrics	47	52	educational research	23	38
primary education	47	81	gifted education	23	38
social sciences	47	101	graduate education	23	28
ınformation technology	47	63	human capital	23	23
evaluation	46	70	management	23	35
teaching/learning strategies	46	80	physics education	23	25
steam education	45	45	academic performance	22	33

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
environmental education	44	57	citizen science	22	28
scientific literacy	44	47	educational innovation	22	43
ınformation literacy	44	60	k-12	22	34
collaborative learning	42	71	pandemic	22	53
elementary education	42	82	physical education	22	33
research	42	70	science learning	22	32
universities	42	59	sts	22	33
pre-service teachers	41	57	teacher	22	45
social media	41	53	competence	21	25
teachers	41	80	curriculum design	21	27
data science	40	70	data science applications in education	21	29
engagement	40	71	design thinking	21	28
high school	40	54	faculty development	21	28
systematic review	40	61	graduate education/research	21	30
critical thinking	39	45	identity	21	37
tpack	39	55	laboratory ınstruction	21	33
attitudes	38	67	libraries	21	38
distance learning	38	50	literature review	21	32
learning analytics	38	39	nanotechnology	21	23
machine learning	38	71	persistence	21	41
problem-based learning	38	63	primary school	21	34
programming	38	89	survey	21	34
communication	36	68	teaching and learning	21	23
gamification	36	60	undergraduate education	21	22
china	35	29	digitalization	20	28
collaboration	35	51	doctoral education	20	24
culture	35	63	education policy	20	15
flipped classroom	35	62	elementary school	20	29

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
science communication	35	30	employability	20	33
student engagement	35	49	engineering design	20	21
attitude	34	64	faculty	20	43
entrepreneurship	34	60	gender differences	20	26
first-year undergraduate/general	34	45	innovation	20	30
mentoring	34	68	leadership	20	28
middle school	34	61	mobile technology	20	26
robotics	34	72	Mooc	20	32
ethics	33	56	skills	20	30
improving classroom teaching	33	55			

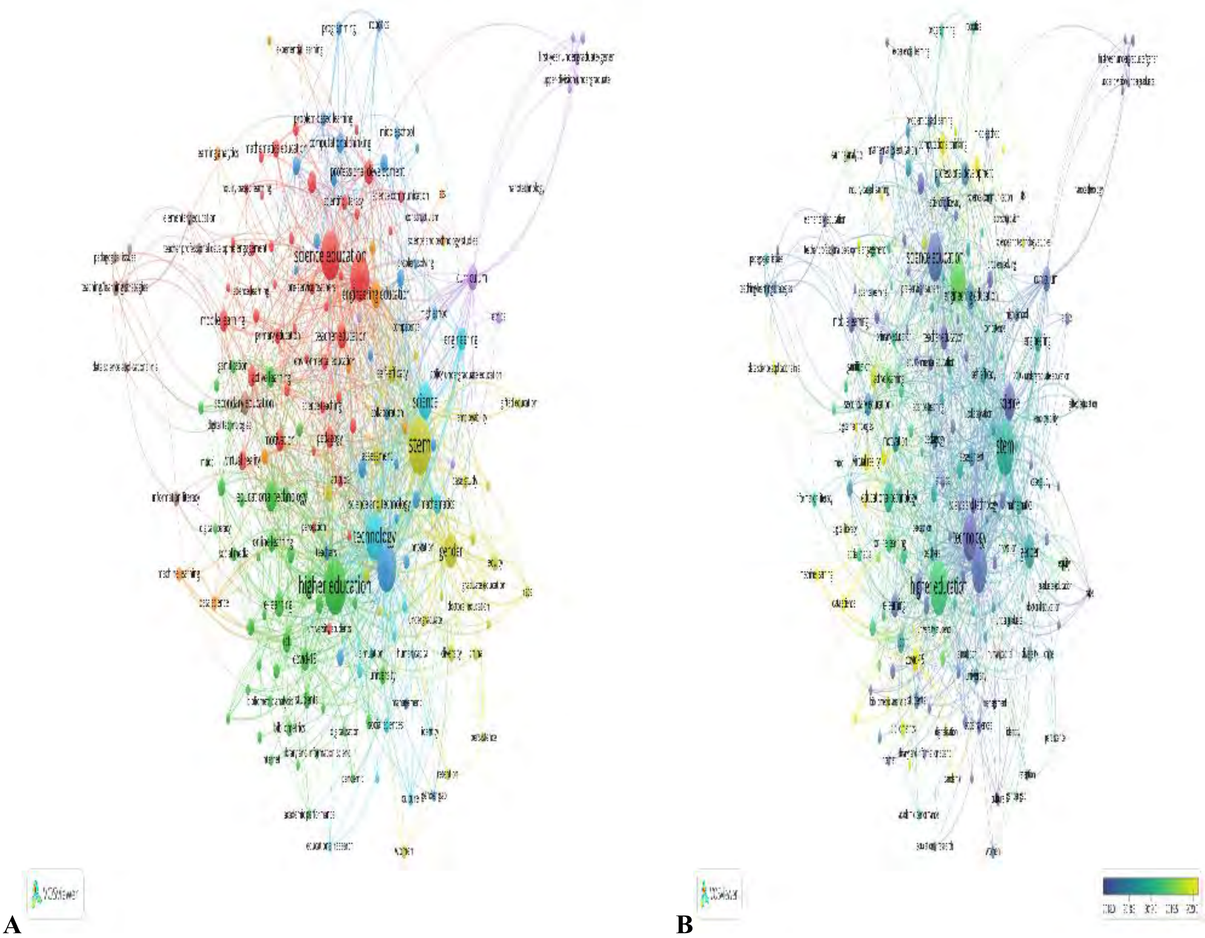


Figure 2. The Nexus of documents' Keywords Clusters (A) and Trend of These Clusters (B)

According to the keyword analysis, a quite number of clusters were retrieved. Accordingly, 8 clusters were identified. When the map consisting of keywords related to "science education and technology" in Figure 2-A is examined, it is seen that five main clusters (yellow, blue, red, green, turquoise) and relatively smaller clusters are formed.

The prominent term in the red cluster is “science education” [Total Link Strength (TLS=494, Links=130)]. This finding is not surprising at all, as science education studies were examined in this study. This term is followed by keyword “stem education." [Total Link Strength (TLS=445, Links=127)]. STEM Education provides possibilities for students beyond the siloed science, technology, engineering, and mathematics subject matter (Kaya-Capocci & Peters-Burton, 2023).

The keyword with the highest node density in the blue cluster is “education" [Total Link Strength (TLS)=736, Links=144]. Regarding this issue, Pesta et al. (2018) stated in their study that “education” might attract relatively more research interest because the keyword is broadly multi-disciplinary. After “education”, the terms “computer science education”, “computational thinking” stand out.

The strongest node of the green cluster is the “higher education” keyword [Total Link Strength (TLS)=817, Links=150]. Regarding this issue, Jamoliddinovich (2022) stated that the widespread introduction of new pedagogical technologies in teaching to students of higher education institutions and the effective use of innovative technologies are the main support for improving the quality of education. Also, Over the last years, educational technology in Higher Education has been promoted as having the potential to transform teaching and learning (Conole, 2014; Laurillard, 2008; Englund et al., 2017). In the same cluster, after "higher education", the keywords "learning", "educational technology", "covid19" draw attention.

The strongest node of the turquoise cluster is the “technology” keyword [Total Connection Strength (TLS=731, Links=151)]. Since we examined the studies on technology in science education, it is not surprising that the keyword technology came up. This term is followed by the keywords “science”, “engineering".

The keyword with the highest node density in the yellow cluster is “Stem” [Total Link Strength (TLS)=926, Links=153]. The reason why the STEM approach is important is the thought that it provides benefits in many areas in education. Many reasons such as progress in science and technology (Aydeniz, 2017), interest in STEM disciplines, especially science and mathematics (Czerniak, 2007; Morrison, 2006), have led countries to turn to STEM. This term is followed by the keywords “gender”, “assessment".

The findings obtained in the study were analyzed in two different dimensions. The second dimension of the analysis is the time trend. According to the keyword analysis time trend, in recent studies on science education and technology, "COVID 19, "virtual reality", "computational thinking" etc. it is seen that the words are mentioned (Figure 2-B). This finding may be an indicator of new research interests of researchers working in science education.

Term Analysis: Most Common Terms in the Publications

To determine the most common terms through the retrieved documents, it was considered 200 documents as the minimum occurrences of a term. Out of the 128765 terms, 226 terms met the relevant threshold. For each of 226 terms, a relevance score was calculated. Accordingly, the most relevant terms were selected. Here in, the default choice was to select the 60% most the relevant terms. Finally, 136 terms were selected for further analysis of visualization and networks among the terms (see Table 2).

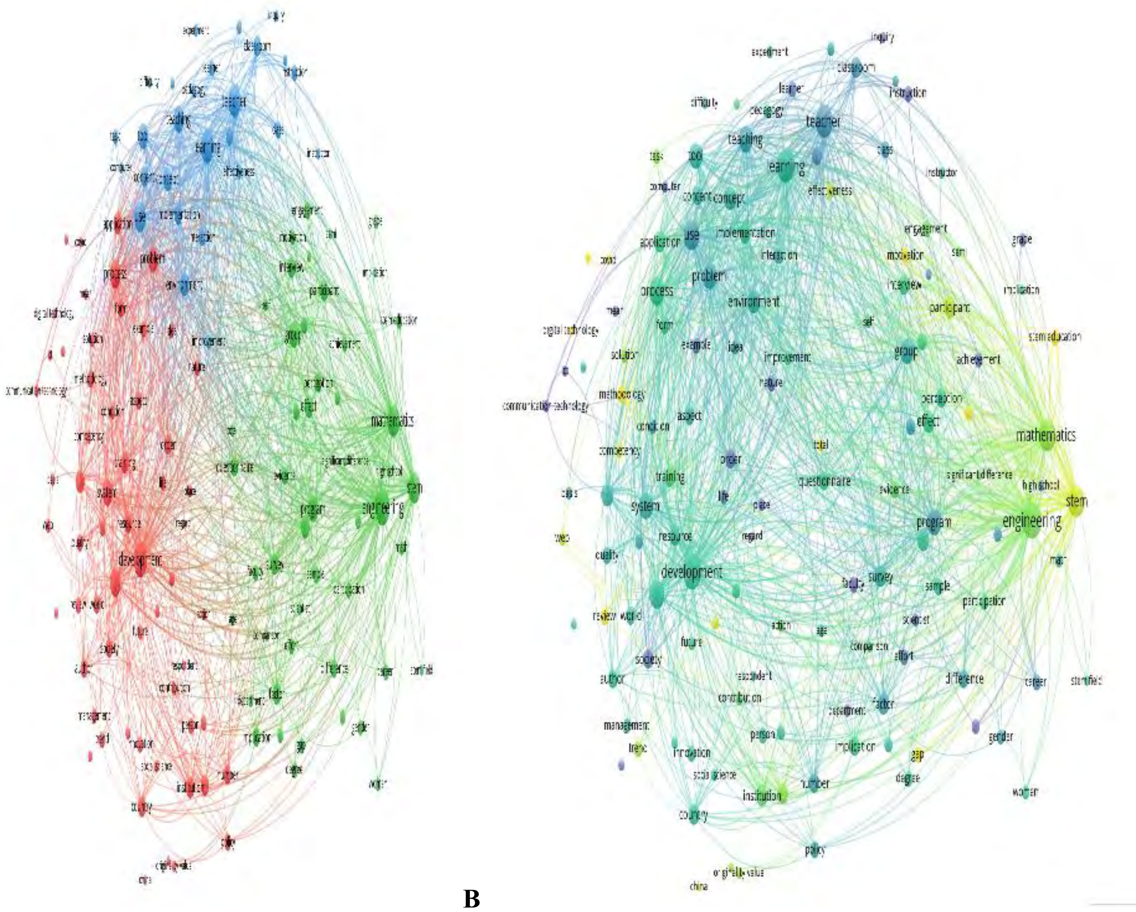
Table 2. The Most Common Terms Retrieved from the Publications

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
engineering	2739	28.584	nature	524	0.2743
development	2370	0.3717	example	520	0.4063
learning	2248	0.2758	structure	499	0.3207
mathematics	2152	31.427	communication	498	0.6733
teacher	2101	0.2494	life	498	0.4254
stem	1954	46.152	motivation	496	0.2954
use	1899	0.6234	achievement	489	0.5571
process	1779	0.4658	effectiveness	489	0.1935
article	1692	0.4848	success	487	14.933
program	1510	0.461	management	479	13.727
teaching	1507	0.3378	gender	473	38.606
system	1432	0.5776	idea	468	0.3535
group	1321	0.2737	task	466	0.6812
problem	1318	0.2804	culture	460	0.3079
tool	1291	0.5	influence	460	0.2381
environment	1265	0.3103	college	459	22.559
effect	1093	0.452	improvement	445	0.2535
concept	1065	0.3276	lesson	440	0.4016
information	1060	11.653	intervention	436	0.6039
institution	1005	0.3571	contribution	430	0.2647
factor	1000	0.3062	competency	417	0.5529
survey	989	0.3115	solution	412	0.5483
application	987	0.506	condition	406	0.7999
interest	975	0.4625	woman	400	72.694
participant	960	0.4332	web	399	22.463
classroom	947	0.385	future	392	0.3704
higher education	944	0.247	math	391	46.295
training	910	0.5486	pedagogy	386	0.2563
interview	892	0.3714	grade	380	17.466

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
implementation	861	0.2438	demand	370	0.5429
country	859	0.6331	place	369	0.3015
implication	852	0.3508	communication technology	364	29.916
perception	849	0.4526	department	348	0.1581
content	830	0.418	computer science	346	0.2532
number	814	0.1628	age	345	0.1684
resource	803	0.5563	self	340	0.2046
order	796	0.3487	social science	340	0.6656
questionnaire	766	0.3707	scientist	331	0.3169
society	764	0.8776	basis	329	15.881
difference	709	13.582	experiment	329	0.5861
author	707	10.481	action	320	0.2326
aspect	700	0.5224	total	320	0.2927
world	686	0.6688	computer	310	0.8947
science education	683	0.3615	end	309	0.2457
attitude	662	0.3639	inquiry	308	0.645
sample	655	0.4851	library	308	2.709
performance	653	0.264	ıct	302	26.005
evidence	650	0.2884	high school	296	25.107
class	649	0.3069	reflection	286	0.3879
form	641	0.559	mean	281	0.9664
quality	632	0.8514	professional development	280	0.4874
policy	630	0.4691	comparison	276	0.1248
methodology	622	0.51	instructor	270	0.5583
engagement	594	0.3291	difficulty	268	0.3131
career	590	42.131	originality value	265	32.943
person	588	0.2195	possibility	264	12.303
effort	583	0.3736	ımplication	261	14.904
participation	577	12.551	significant difference	259	11.389
learner	574	0.3923	design methodology approach	256	33.747
review	569	0.9173	COVID	240	23.681
degree	558	0.8155	semi	236	0.7519
faculty	554	0.2231	information	235	19.295

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
			technology		
interaction	541	0.3337	stem field	235	94.032
trend	541	0.9502	pandemic	224	27.609
innovation	539	0.7205	digital technology	222	20.785
gap	534	10.938	respondent	221	0.7267
stem education	530	32.347	regard	213	0.2937
instruction	526	0.4768	china	212	10.392

According to these findings, “engineering” (f=2739) is among the most common terms in studies. The words “development” (f=2370), “learning” (f=2248) 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 “stem field” (R.Sc: 94.032); “woman” (R.Sc: 72.694); “math” (R.Sc: 46.295) are included (Table.2). In term analysis, 3 clusters were identified (Figure 3-A). Cluster-1 (red) consists of 60 terms. The most prominent are the terms “development”, “article”, “system”. Cluster-2 (green) consists of 49 terms, most notably the terms “engineering”, “mathematics”, “stem”. Cluster-3 (blue) consists of 27 terms, most notably the terms "learning", “teacher”. In addition, in the temporal network analysis graph shown in Figure 3-B, the yellow color shows the terms used in the documents made in recent years.



A B

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

Countries Analysis: Most Published Countries of the Publications

To reveal the spatial distribution of the reports, we further performed country analysis. According to the retrieved documents, 226 countries published documents, in this regard. However, it set 30 documents as the minimum number of documents of a country and 56 countries were revealed (see Table 3). For each of the 56 countries, the total strength of the co-authorship links with other countries were calculated. Moreover, the total citation of documents per country was also given. The countries with the greatest total link strength were selected for subsequent analysis.

Table 3. The Most Countries Published of the Documents

Country	Documents	Citations	Total Link Strength
United States	2651	40331	2191
Spain	519	5453	479
Turkey	457	3505	609
United Kingdom	454	7289	472
Australia	404	5401	544
Russian Federation	383	1291	82
China	366	2587	381
Canada	270	4172	394
Brazil	243	937	45
Taiwan	236	3860	489
Malaysia	201	1475	291
Germany	198	2428	204
South Africa	187	992	104
India	168	1164	49
Indonesia	132	560	177
Netherlands	125	2469	204
Hong Kong	118	1541	344
Sweden	117	1644	100
Finland	112	1724	173
Mexico	111	470	38
South Korea	110	1008	173
Portugal	92	673	60
Israel	91	1436	201
Italy	90	720	44
Japan	87	647	41
Iran	80	676	38
Greece	73	1073	110
Norway	72	915	91
New Zealand	71	878	81

Country	Documents	Citations	Total Link Strength
Thailand	69	445	87
France	68	805	30
Nigeria	66	262	34
Ireland	65	558	131
Kazakhstan	61	279	18
Belgium	60	1127	138
Colombia	60	307	44
Saudi Arabia	58	844	73
Chile	54	243	67
Switzerland	53	598	43
Denmark	50	1122	53
Pakistan	48	710	30
Ukraine	48	132	13
Singapore	45	564	83
Poland	44	244	18
United Arab Emirates	43	863	57
Slovenia	42	377	48
Jordan	41	286	25
Cuba	39	61	5
Austria	36	666	80
Cyprus	36	319	78
Philippines	36	157	31
Slovakia	36	242	19
Croatia	35	190	11
Serbia	33	832	53
Ghana	32	111	0
Argentina	31	94	24

The citation network covers 56 countries. Countries are represented by nodes. A greater number of nodes indicates a greater number of broadcasts. Connection refers to lines between countries. Accordingly, in this study, it is seen that United States has more important nodes with 40331 citations (Table 3). It is seen that United Kingdom is in the second place with 7289 citations. These countries are followed by Spain with 5453 citations and Australia with 5401 citations. Overall, in the global broadcast share of 56 countries, United States ranks first with 2651 publications, followed by Spain (519 publications), Turkey (457 publications) (Table 3). According to this study, the USA is the most productive country with 2651 publications. This supports the view that the USA is one of the leading countries in the field of science education (Demir and Selvi, 2018; Yurdakul and Bozdoğan, 2022). The findings regarding the frequency and the citation relationship between them were analyzed in two different dimensions. The first is the cluster size. According to this analysis, 8 clusters with a high citation relationship were identified. The first cluster (red) includes Australia, Austria, Germany, Greece, Ireland, Philippines, Poland, Russian Federation, Serbia, Slovakia, Spain, Switzerland, Ukraine, United Kingdom, United States. Cluster 2 (green) Canada, Chile, Cyprus, Denmark, Finland, Italy, Jordan, Kazakhstan, Nigeria, Pakistan, Saudi Arabia, Sweden, United Arab Emirates; Cluster 3 (blue) Belgium, Brazil, Croatia ,Cuba, France, India, Mexico, Netherlands, New Zeland, Portugal, South Africa; Cluster 4 (yellow) China, Hong Kong, Indonesia, Iran, Malaysia, Singapore, Taiwan, Thailand, Turkey; Cluster 5 (purple) Israel, Japan, Norway, Slovenia; Cluster 6(turquoise) Argentina, South Korea; Cluster 7(orange) Ghana; Cluster 8(brown) contains the Colombia (Figure 4-A).the second dimension of the analysis is the time trend. Provided that the assumptions in the cluster analysis obtained above are valid, the time trend of the citation pattern is obtained. The most important result obtained in the time trend analysis is the identification of China, Australia as new citation foci. (Figure 4-B)

A

B

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

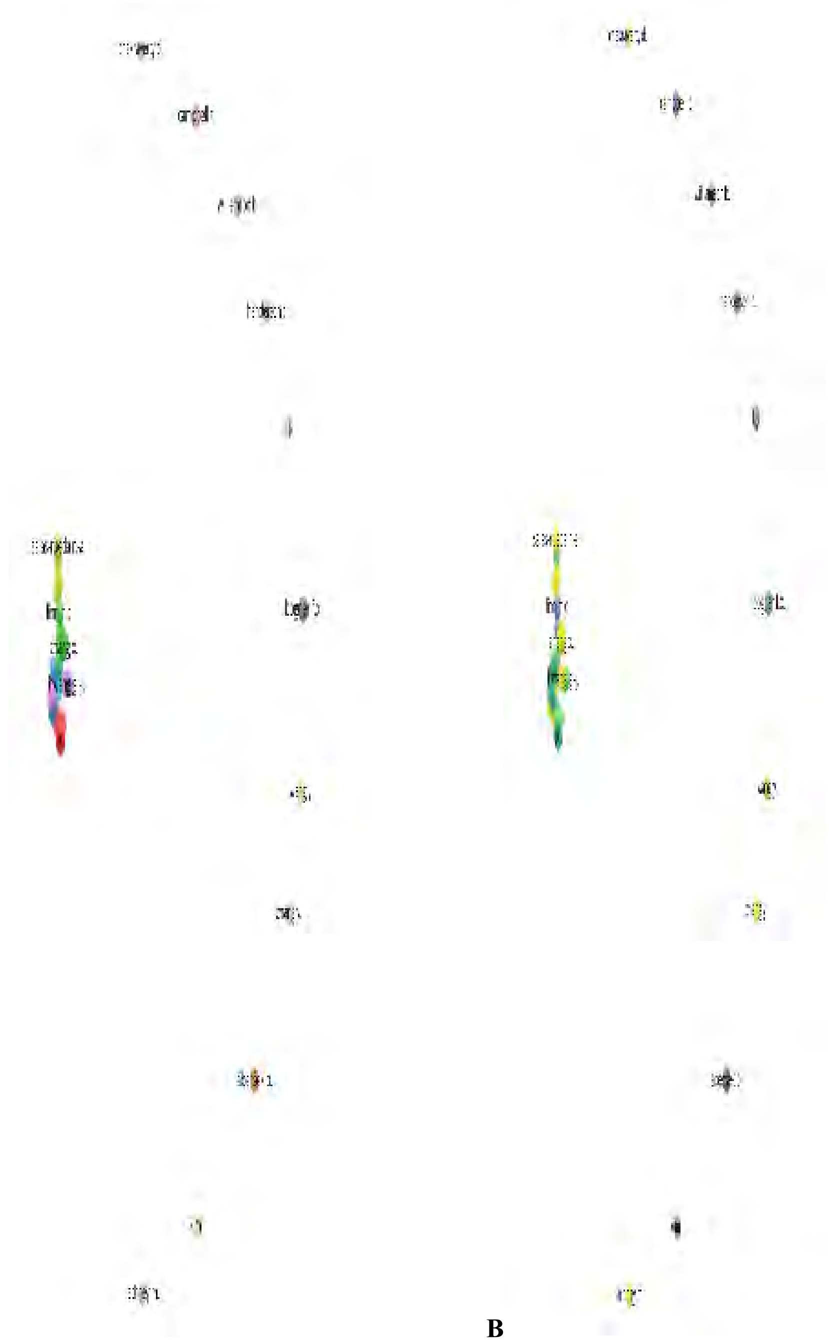
Author Citation Analysis: Most Productive Authors in the Documents

In order to reveal the relationship between the authors with a clearer analysis, authors who contributed at least 8 documents were selected. Out of a total of 21602 authors, 45 meet the relevant threshold.

Table 4. Most Productive Authors in the Documents

Author	Documents	Citations	Total Link Strength
Jr. H.	29	474	5
Wang X.	19	656	3
Hwang G.J.	16	703	16
Zhang X.	15	67	5
Bogner F.X.	13	91	1
Salas-Rueda R.-A.	13	23	1
Aberšek B.	12	137	2

Author	Documents	Citations	Total Link Strength
Campbell T.	12	215	0
Barak M.	11	294	1
Chen X.	11	229	5
Roehrig G.H.	11	195	3
Wang J.	11	40	1
Zhang J.	11	62	1
Capraro M.M.	10	484	13
Li J.	10	82	0
Wang Y.	10	13	0
Chakraverty D.	9	148	0
Henderson C.	9	250	0
Kim J.	9	53	0
Lavicza Z.	9	32	5
Lin K.-Y.	9	127	7
Linn M.C.	9	200	3
Tsai C.-C.	9	270	6
Wang S.	9	402	3
Wu J.	9	89	1
Xie C.	9	197	24
Zhang L.	9	34	1
Zhang M.	9	86	1
Zhang Y.	9	19	0
Avsec S.	8	28	2
Capraro R.M.	8	154	7
Chai C.S.	8	284	23
Chang C.-Y.	8	88	11
Chen G.	8	129	21
Herro D.	8	235	6
Jong M.S.-Y.	8	204	18
Lachney M.	8	65	0
Li L.	8	31	1
Love T.S.	8	28	7
Sonnert G.	8	202	5
Wang C.	8	19	1
Williamson B.	8	317	0
Wu H.-K.	8	177	5
Xing W.	8	243	21
Yang Y.	8	53	2



A B

Figure 5. The Most Cited Authors (Co-Citation Analysis) (A) and Trend of These Clusters (B)

In this study, Jr. He has been the most prolific author with 29 works. Wang x is the second most prolific author with 19 works. Also, In the research, hwang g.-j. He is the most cited author with 16 publications. The map of the Authors' co-authorship network created with Vosviewer is shown in Figure 5-A. In addition, in the temporal network analysis graph shown in (Figure 5-B), the yellow color shows the authors who have published and collaborated in recent years.

In the literature, there are different methods used to measure the productivity of the authors, called the 80/20 rule, also known as the Pareto Law, the Price Law and the Lotka Law (Erbaşı, 2017). According to the 80/20 rule, 80% of the total articles should be written by 20% of the authors (Egghe & Rousseau, 1990, pp. 361-362). Accordingly, 80% (6808 articles) of the 8511 articles published in this study should have been written by 20% (4320 authors) of a total of 21602 authors. In the evaluation, it is seen that 20% of the authors (4320 authors) of the published articles wrote 63% of the total article (8511 articles). It is seen that the published articles do not comply with the 80/20 rule.

Price's Law is a measurement method that predicts that the square root of the total number of authors writes half of the total article in the literature (Egghe and Rousseau, 1990, p. 362). Accordingly, in this study, a total of 21602 authors should have written the square root (146 authors), half of 8511 articles (4255 articles). In the evaluation, it is seen that the 146 most productive authors wrote 1078 articles, so the journal does not comply with Price's law.

Lotka's Law, which is another method in the literature, is the number of two writers in a certain field, about 1/4 of a writer; the number of three writers, 1/9 of a writer; The number of people who wrote n articles is about 1/rf of a writer, and the rate of those who write an article is about 60%. It is a measurement method that predicts that 15% of the authors who publish in a journal contribute with two articles, 7% with three articles, and 3.75% with 4 articles (Lotka, 1926; cited in Yılmaz, 2006, p.63). Accordingly, in this study, 87% (18923 authors) wrote one article, 8.5% (1847 authors) two articles, 2% (445 authors) three articles and 0.7% (172 authors) wrote four articles. According to the findings, although this study does not comply with the Lotka Law, results are sorted by a similar ratio.

Journal Analysis: Most popular journals in the publications

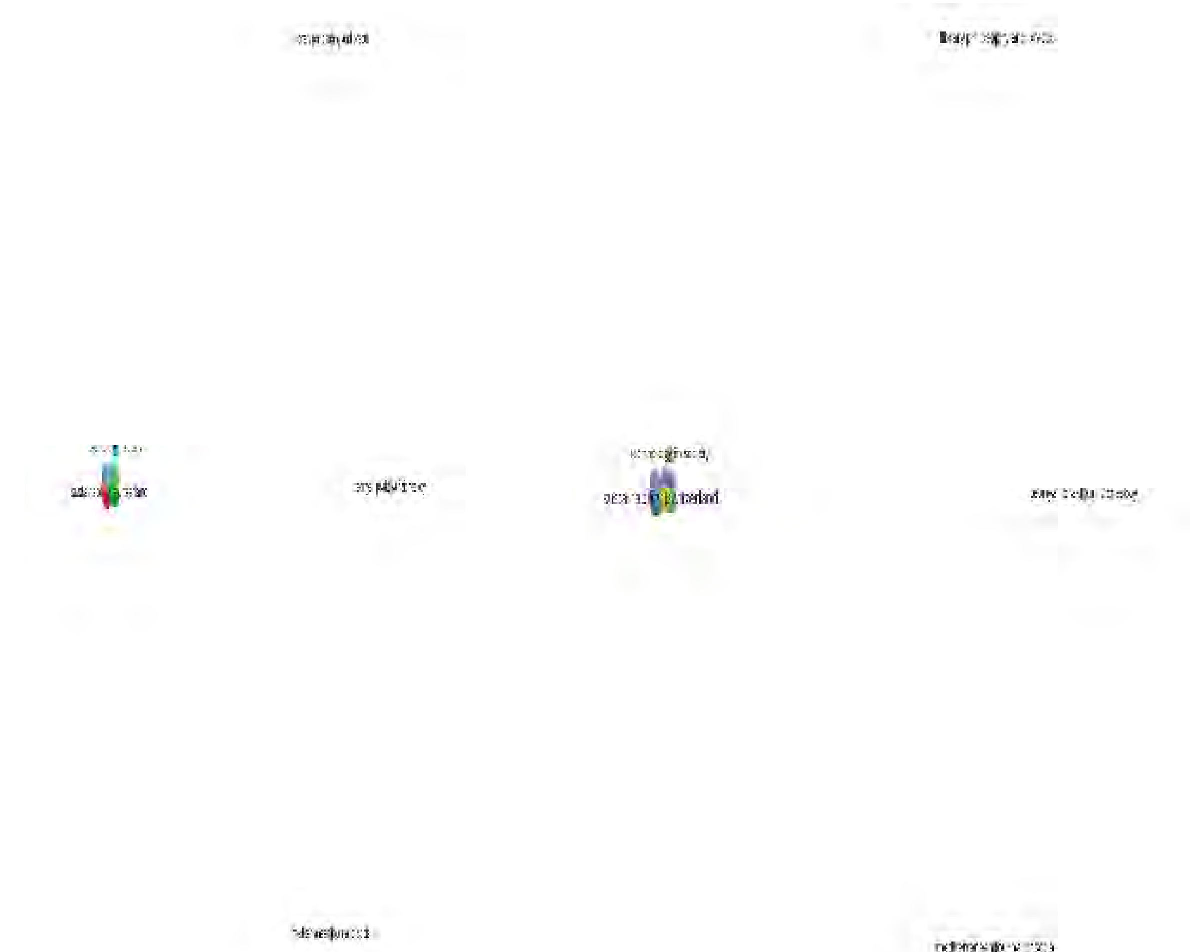
In order to determine the most preferred journals over the obtained documents, sources with at least 30 publications related to the subject were selected. Out of a total of 1660 sources, 43 meet the relevant threshold (see Table 6). Accordingly, "Computers and Education" (156 documents, 7852 citations), "CBE Life Sciences Education" (164 documents, 4414 citations), "International Journal of Technology and Design Education" (148 documents, 2335 citations) were the most cited journals in the studies. In addition, it has been determined that the most publications are "Sustainability (Switzerland)" (214 documents), "CBE Life Sciences Education" (30 documents) (see Table 5).

Table 5. Most Popular Journals in the Documents

Source	Documents	Citations	Total Link Strength
Sustainability (Switzerland)	204	2278	98
CBE Life Sciences Education	164	4414	95
Computers and Education	156	7852	188
International Journal of Technology and Design Education	148	2335	177
Education and information Technologies	137	1335	67
Journal of Science Education and Technology	134	2319	177
Education Sciences	124	1072	95

Eurasia Journal of Mathematics, Science and Technology Education	105	1494	126
Journal of Chemical Education	84	1135	35
International Journal of Emerging Technologies in Learning	80	518	24
International Journal of Engineering Education	74	281	18
International Journal of Science Education	71	1201	98
International Journal of Stem Education	67	1297	94
Computer Applications in Engineering Education	64	690	27
Frontiers in Education	62	124	49
Journal of Research in Science Teaching	60	1724	119
International Journal of Science and Mathematics Education	60	1166	98
Cultural Studies of Science Education	58	496	34
Journal of Baltic Science Education	53	349	53
Turkish Online Journal of Educational Technology	52	164	5
BMC Medical Education	50	1011	10
British Journal of Educational Technology	49	983	33
Library Philosophy and Practice	48	105	0
Universal Journal of Educational Research	48	167	18
Research in Science and Technological Education	46	283	49
Research in Science Education	46	963	53
Science and Education	42	430	65
IEEE Transactions On Education	42	651	14
Journal of Geoscience Education	41	512	18
World Transactions On Engineering and Technology Education	41	59	5
Canadian Journal of Science, Mathematics and Technology Education	35	307	24
African Journal of Research in Mathematics, Science and Technology Education	34	203	4
Journal of Women and Minorities in Science and Engineering	34	325	16
Sage Open	34	190	9
Journal of Turkish Science Education	33	202	35
Obrazovanie I Nauka	33	149	4
Science Education	33	834	66
Journal of Science Communication	32	198	4
Teoriya I Praktika Fizicheskoy Kultury	32	39	0
Technology in Society	31	418	1

Mediterranean Journal of Social Sciences	30	48	0
international Journal of Science Education, Part B: Communication and Public Engagement	30	213	24
international Journal of Scientific and Technology Research	30	70	1



A B

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

Looking at the map created with VOS viewer, the most cited journals are gathered around 9 clusters (Figure 6-A), and Figure 6-B shows that the “frontiers in education”, “Sustainability (Switzerland)”, “obrazovanie i nauka” journals have been preferred by researchers in recent years, according to the time trend analysis. In the analysis, 9 clusters were identified. Cluster-1 (11 items), Cluster-2 (11 items), Cluster-3 (6 items), Cluster-4 (6 items), Cluster-5 (3 items), Cluster-6 (3 items) contains. Others contains 1 item. There are links around some clusters. Here, a node can have a large number of connections with other nodes, allowing it to be in a central location in the cluster. In addition to the number of connections a node has, it will be more useful to evaluate its advantageous position in the cluster with the criteria of proximity and in-betweenness. When the social network is examined, it is seen that relations are mostly knotted through publications such as "Computers and Education, " "International Journal of Technology and Design Education" and "Sustainability (Switzerland)". This shows that these journals have a very important position in the network.

Conclusion

The objective of this study is to reveal the content analysis and trends of studies on science education and technology. In this context, studies on technology in science education scanned in the Scopus database were subjected to bibliometric network analysis. When the trend of 8511 publications including studies on technology in science education was examined, the researcher discovered the following data:

1- It is seen that there are fluctuations in the number of publications over the years, it is seen that the studies are increasing gradually and peaked with a total of 1416 studies in 2022.
2- 191 keywords detected in research. According to the keyword analysis, a quite number of clusters were retrieved. It showed that the most frequently used keywords in publications were "science education", "technology", "Stem", "higher education", "education."
3- To determine the most common terms through the retrieved documents, 136 terms were selected for further analysis of visualization and networks among the terms. Among the high relevance scores are "stem field"; "woman"; "math".
4- It set 30 documents as the minimum number of documents of a country and 56 countries were revealed. In this study, it is striking that United States has more important nodes with 40331citations. It is seen that United Kingdom is in the second place with 7289 citations. These countries are followed by the Spain with 5453 citations and Australia with 5401 citations.
5- Author analysis was performed for authors with at least8 publications. Out of a total of 21602 authors, 45 meet the relevant threshold. Jr. He is the author who has done the most work on this subject with 29 publications. In addition, it was determined that Lotka's law, which is one of the methods used to measure the productivity of the authors, did not comply with this study.
6- In order to determine the most preferred documents, documents with at least 30 publications related to the subject were selected. Out of a total of 1660 sources, 43 meet the relevant threshold.
7- Accordingly, "Computers and Education", "CBE Life Sciences Education", "International Journal of Technology and Design Education" were the most cited sources in the studies.

Recommendations

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

1- Research on give importance to identifying of technology in science education must be continued.
2- Although there are many keywords in the analysis, studies containing other keywords should be emphasized about technology in science education.
3- 136 terms were selected for further analysis of visualization and networks among the terms. Studies containing other variable should be emphasized about technology in science education
.4- The study is limited to published documents about technology in science education. Researchers could conduct more detailed technology in science education using various keywords in order to recognize fundamental research in the selected area of research and also to benefit from these documents.
5- The study is limited to research found in Scopus database. Further studies could use other indexes.
6- Further studies could be conducted using different limitations when searching for the documents.

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