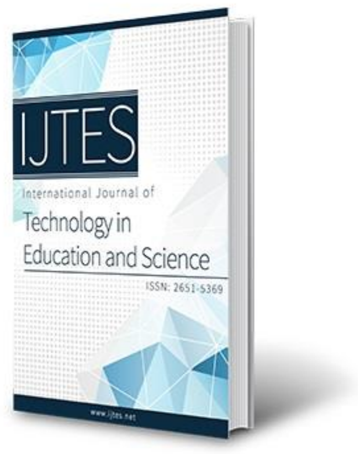

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An Examination of the Studies on STEM in Education: A Bibliometric Mapping Analysis

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An Examination of the Studies on STEM in Education: A Bibliometric Mapping Analysis

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Abstract

This research aims to propose a bibliometric map of studies on the use of STEM in education. This study used publication co-citation analysis, author co-citation analysis, and word frequency analysis methods to reveal the structure and transformation of STEM literature. Descriptive data such as the distribution of studies in the field by country, institution, and time were obtained from the Web of Science (WoS) database. We used the RStudio program for bibliometric analysis. The International Journal of Stem Education is the most widely published. Journal of Science Education and Technology received the most citations. Guzey S.S. is the author with the most publications on the subject. Capraro M.M. most cited author. The university that publishes the most is Purdue University. The USA is the country with the highest number of publications. The paper by Blickenstaff titled Gender and Education in 2005 has been cited the most worldwide. The research by Maltese, which was published in 2019, had the highest local citation rate. According to the results of cluster analysis, four clusters were formed. The term "STEM" appears to be present in all clusters. "STEM Education" was also included in three clusters.

Introduction

Today, changing science and technology brings innovations in human life. Keeping up with this change and development has become necessary for people of our age. Critical issues and problems such as the global economic race, the move of the industry to different dimensions, the development of artificial intelligence, and the inadequacy of energy resources have led to a change in the knowledge and skills that today's people should face today (Castells et al., 1999; Heeks, 2002; Sampler 1998).

Changes in the knowledge and skills that people should have brought along with the reforms that need to be made in the countries' education systems. The countries that have realized these reforms are leading in the global economic race. Perhaps one of the fundamental reasons for this situation is that these countries are aware of the communication between science, technology, and education, renew their education policies in line with their needs, and constantly update their science and mathematics curricula to the needs of the developing age (White, 2018). Mainly to keep up with our generation's rapidly developing science and technology, it is essential to provide individuals with 21st-century skills such as innovative and critical thinking, problem-solving, communication, group work, and research (Chalkiadaki, 2018; Van Laar et al., 2020).

Developed and developing countries have recently been seriously engaged in Science, Technology, Mathematics, and Engineering (STEM) education (Li et al., 2020; Simarro & Couso, 2021). Especially in the USA, STEM integration is being used increasingly (Nxumalo & Gitari, 2021). China, Japan, South Korea, and most European Union countries apply student and design-centered STEM education to train individuals. (Loyalka, 2021, Ryu et al., 2021). STEM abbreviation has emerged by combining the English initials of Science, Technology, Engineering, and Mathematics (National Research Council, 2012). What is meant by the STEM approach is a design-oriented process in which students actively participate by combining engineering and technology with science and mathematics (Reiser, 2013).

STEM Education

There is no common definition of what is STEM in the literature. (Srikoom et al., 2018). For example, Sanders (2012) states STEM as a learning or teaching approach using two or more STEM disciplines. In Johnson et al. (2020) definition, STEM is a teaching approach that integrates science and mathematics teaching with scientific inquiry practices, technology and engineering design, mathematical analysis, and 21st-century interdisciplinary themes and skills. Some researchers, on the other hand, have seen the design process that engineering includes as a learning environment for the STEM approach and have created models on this basis (Kelley & Knowles, 2016). Stohlmann, Moore, and Roehrig (2012) describe it as an effort to connect the fields of science, technology, engineering, and mathematics in a course through the connections between these fields and real-life problems.

Although there are different definitions and approaches as a definition, these definitions have common points. (Shrikoomet al., 2018). Moore, Johnson, Peters-Burton, and Guzey (2015) listed the essential features of the STEM approach as follows:

-it has a motivating context,
-it includes an engineering design task,
-it provides learning from failure,
-it is based on curriculum-based science/mathematics gains, and
-it is student-centered.

It includes teaching and group work and gives importance to communication. Revealing these commonalities is essential to understanding what STEM is and what it is. Calling traditional teaching combined with science and mathematics teaching STEM and using an outdated curriculum is insufficient to increase students' interest in STEM fields or their higher education in these fields (Oner et al., 2016). From this point of view, the definition of STEM adopted by the authors in this study is an approach that includes at least two STEM components, produces solutions to students' daily life problems, and uses technology and the engineering design process in this process.

Various reports published in the USA for the last ten years have emphasized the importance of STEM education in increasing the economic workforce and maintaining scientific leadership (Outlook, 2014). Similarly, strategic plans are being made for STEM education in many European countries, and it aims to increase the success of the disciplines in STEM fields and develop the students' abilities (McLoughlin et al., 2020). In summary, educational strategies for STEM education have begun to be developed, and changes have been made in different countries.

Related Studies

Özkaya made a bibliometric analysis of the studies in the WoS database between 1992 and 2017 in the subject area of STEM education. Some of the noticeable results of this study are as follows. After 2008, an acceleration was observed in the increase in the number of studies. The number of citations to studies has increased in recent years. The most cited journals are the Journal of Research in Science Teaching and The Journal of Educational Research. According to the keywords' analysis, it is seen that the most used concepts are the keywords "education," "STEM," and "science." The USA is the country that contributes the most.

In 2016, Yu, Chang, and Yu conducted a bibliometric analysis of STEM education. The authors revealed that between 1992 and 2013, the USA, England, Netherlands, Australia, and Spain contributed most to STEM education, respectively. In this study, the countries with the most central position were the USA, England, Australia, Netherlands, and Ireland, respectively. The authors found the most used words in the years mentioned as "STEM," "science education," "STEM education," "higher education," "education," and "science." The authors found the journals directing STEM education as International Journal of Science Education, Journal of Science Education and Technology, Journal of Engineering Education, Teachers College Record, and Research in Higher Education, respectively.

Aseffa and Rorissa conducted a bibliometric analysis of STEM education in 2013. The authors analyzed the titles, keywords, and abstracts of the articles. In this way, they tried to determine the primary knowledge areas that characterize the field of STEM education with the co-occurrence analysis. When the keywords related to STEM education are examined according to their titles, the most used keywords are "education," "science education," "technology education," "mathematics education," and "engineering education," respectively.

Importance of the Study and Research Questions

In general, the increase in the number of people/organizations studies on STEM education indicates that national and international studies in STEM education will gradually increase, and STEM education will take place more in education programs. It is recommended that researchers studying STEM education pay attention to publications with citations, authors with citations, words with the highest frequency and centrality values, and words with citations; because it is seen that these concepts will frequently appear shortly. Citation analysis helps identify transdisciplinary commonalities and differences among important articles, key journals, and influential authors (Biehl, Kim, and Wade, 2006). Citation analysis is regarded as critical in terms of investigating the historical condition of the main topic of study in a field and the comparative impacts of various studies (Donthu et al., 2021). Citation analysis may help researchers uncover popular study subjects, approaches, and research trends and comprehend components in major issues (Chen et al., 2021).

When the studies carried out with STEM in the literature are examined, it is frequently encountered in national and international studies that evaluate the articles published in journals, graduate theses, and papers presented in congresses and symposiums. It can be said that there is a need for current bibliometric studies in the field of STEM education.. In this study, it is crucial to present the current literature in the field of STEM education from a bibliometric perspective. In this context, this research aims to propose a bibliometric map of studies on the use of STEM in education. We sought answers to the following research questions for this purpose:

1. Which journals are the most influential in STEM education?
2. Who are the most influential authors in STEM education?
3. Which universities and countries are the most influential in STEM education?
4. What is the status of STEM citations in education?
5. What are the keywords and trending topics in STEM education?
6. How do clusters by author coupling emerge in STEM education research?

Method

This study used publication co-citation analysis, author co-citation analysis, and word frequency analysis methods to reveal the structure and transformation of STEM literature. Descriptive data such as the distribution of studies in the field by country, institution, and time were obtained from the Web of Science (WoS) database. We used the RStudio program for bibliometric analysis.

Data Collection Tool

We used the WoS database to obtain the bibliometric data examined in this study. The WoS database is accepted as the world's leading academic database with the abundance and diversity of the publications it scans (Pranckutė, 2021). In addition to this feature, the WoS database also provides distribution by countries, scientific fields, journals, etc., regarding the bibliometric data of the publications it scans. It also provides basic statistics. In this study, our search query is "STEM" AND "EDUCATION."

After searching with this query, filtering was done with Education, Educational research from WoS categories. Filtering was applied by selecting Articles as the document type and SSCI, SCI-Expanded, and ESCI indexes from the index. At the end of these searches, we found 3046 articles. The BibTeX of these articles has been downloaded as a Full record in WoS. The meta-data collection consists of seven separate "BibTeX" files since WoS allows up to 500 results to be downloaded at once in the "BibTeX" format. These seven "BibTeX" were combined in Visual Studio Code Editor.

Analysis of Data

Bibliometrics is a quantitative analysis of the bibliographic features of the growing literature (Donthu et al., 2021). It is a quantitative method used to examine the knowledge structure and development of research fields based on analyzing relevant publications (Jusoh et al., 2021). It is often used to identify current status and trends through analysis of publications (Todeschini & Baccini, 2016). In this research, the bibliometric analysis method was used. The bibliometric calculations have been made more understandable and readable by showing figures and tables. We provided descriptive information regarding the obtained data in Table 1.

Table 1. Descriptive Information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1992:2022
Sources (Journals, Books, etc,)	479
Documents	3.046
Average years from publication	3,97
Average citations per document	9,90
Average citations per year per doc	1,80
References	10.6821
DOCUMENT TYPES	
Article	2.757
Article; book chapter	2
Article; early access	279
Article; proceedings paper	8
DOCUMENT CONTENTS	
Keywords Plus (ID)	2.499
Author's Keywords (DE)	6.765
AUTHORS	
Authors	7.183
Author Appearances	9.047
Authors of single-authored documents	472
Authors of multi-authored documents	6.711
AUTHORS COLLABORATION	
Single-authored documents	513
Documents per Author	0,424
Authors per Document	2,36
Co-Authors per Documents	2,97
Collaboration Index	2,65

Table 1 shows that papers on the issue were published in 479 different publications between 1992 and 2022. Every year, an average of 3.97 articles are written on the subject. These articles have received an average of 9,90 citations. Each article obtains 1.80 citations each year on average. There are 472 articles with a single author. Each author has 0.42 articles. Each article has 2.36 writers. The average number of authors per article is 2.97. Figure 1 depicts the annual scientific productivity.

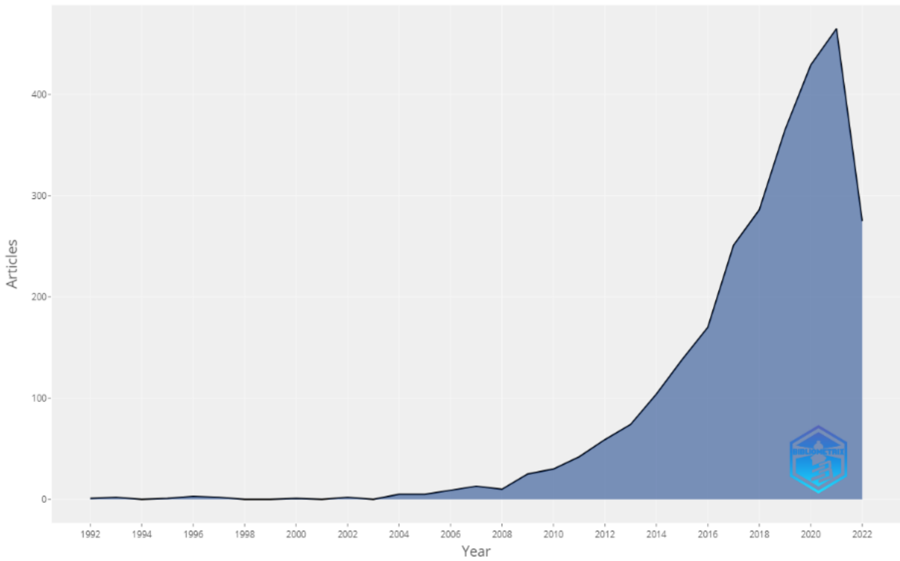

Figure 1. Annual Production

Author and publication co-citation analyses were carried out on these data, including all citations in the co-citation analysis. This resulted in the formation of scattered and difficult-to-interpret images. For this reason, analyses are limited to publications with more than a specific threshold value (White & McCain, 1998). In the literature, there is no definite judgment about what this threshold value should be and how many words should be included in the analysis (Özçınar, 2015). In this study, the most cited publications according to h and g-indexes were included. The h_index calculation is based on a scientist's most cited articles and the number of citations they receive in other publications (Sparkes, 2021). The g-index created by Egghe (2006) defines g2 or more cited publications. For example, if the sum of the citations received by the top 10 (g) publications with the most votes in the selected period is more than 100, and if the total citation (g2) is less than 121 when the eleventh publication is included, the g value for this period is determined as 10.

The standard citation analysis method is based on the idea that citations can be used as abstract symbols related to the research topic, process, or theoretical perspective (Small, 1978). Based on this, the clusters obtained in the co-attribution analysis reflect the intellectual and cognitive structure of the field of study (McCain, 1990). Co-citation analysis method; It can be done at the scale of publication, author, or journal. In this method, the number of coexistences of two publications, authors, or journals in the bibliography of third publications is accepted as a measure of the similarity of the theoretical perspectives, research topics, or methods of these publications, authors, or journals. For example, if publications A and B are cited in publications X, Y, and Z, the joint citation number of A and B is 3. This situation is interpreted as the authors of publications X, Y, and Z think that publications A and B are similar in certain areas. One of the purposes of co-citation analysis studies is to examine the change in the structure of the research field. This method is applied by dividing the period in which the research area is examined into equal parts, creating a co-citation network for each sub-time interval, and integrating these networks. Comparing the standard citation networks created for consecutive time intervals allows us to identify the change and transformation points in the field. In this study, the change in the area was determined by comparing the shared citation network with the RStudio program.

Results

The Most Influential Journals

We reached 3046 articles from 479 journals on the use of STEM in education. The index scores, the total number of citations, number of publications, and publication years of the top 20 journals in this field are presented in Table 2.

Table 2. The Most Influential Journals

Journal	*h*_index	*g*_index	*TC	*NP	*PY_Start
International Journal of Stem Education	18	29	1.325	108	2014
Journal of Science Education and Technology	22	39	1.870	100	2009
International Journal of Science Education	17	27	975	76	1996
Education Sciences	10	13	300	60	2013
International Journal of Science and Mathematics Education	17	26	816	57	
Cultural Studies of Science Education	13	20	515	55	
International Journal of Technology and Design Education	14	27	850	53	
Journal of Research in Science Teaching	20	32	1.118	47	2006
Research in Science Education	10	16	362	46	
School Science and Mathematics	12	27	791	45	2011
Science Education	16	36	1.329	44	
Computers & Education	15	34	1.225	36	2011
Journal of Engineering Education	16	32	1.055	32	2006
Journal of Higher Education	10	20	425	30	2011
Journal of Baltic Science Education	7	10	149	29	2010
Frontiers in Education	4	10	119	27	2019
Eurasia Journal of Mathematics Science and Technology Education	13	19	407	25	2013
Innovative Higher Education	8	13	217	24	2007
Journal of Diversity in Higher Education	13	19	392	22	
Studies in Higher Education	10	16	283	22	2006

*TC=Totatl Citation, *NP=Number of Publications, *PY_Start= Publication Year Start

International Journal of Stem Education (NP=108) is the most widely published journal. Journal of Science Education and Technology (TC=1,870) received the most citations. This journal also stands out as the journal with the highest index scores (h_index = 22, g_index = 39). Journal of Research in Science Teaching (h_index = 20, g_index=32, TC=1.118), Science Education (h_index = 16, g_index=36, TC=1.329), Computers & Education (h_index = 16, g_index=34, TC=1.225) and Journal of Engineering Education (h_index = 16, g_index=32, TC=1.055) are other noteworthy journals. The Bradford's Law analysis results of the publishing journals are shown in Table 3.

Table 3. The Bradford's Law Analysis Results

Journal	Rank	Freq	cumFreq	Zone
International Journal of Stem Education	1	130	130	Zone 1
Journal of Science Education and Technology	2	111	241	Zone 1
Education Sciences	3	97	338	Zone 1
International Journal of Science Education	4	81	419	Zone 1
International Journal of Science and Mathematics Education	5	72	491	Zone 1
Cultural Studies of Science Education	6	69	560	Zone 1
International Journal of Technology and Design Education	7	69	629	Zone 1
Frontiers in Education	8	58	687	Zone 1
Journal of Research in Science Teaching	9	57	744	Zone 1
School Science and Mathematics	10	54	798	Zone 1
Research in Science Education	11	50	848	Zone 1
Science Education	12	50	898	Zone 1
Computers & Education	13	37	935	Zone 1
Journal of Engineering Education	14	35	970	Zone 1
Journal of Baltic Science Education	15	34	1004	Zone 1
Journal of Diversity in Higher Education	16	34	1038	Zone 1

Bradford's Law determines which journals on a topic are core journals. According to this Law, journals are divided into three groups containing the same number of articles. In the first group, the number of journals is small but includes 1/3 of the total articles. These are the core journals. In the second group, the number of journals is higher, and the articles they publish are 1/3 of all articles. In the third group, the number of journals is much more but contains the same 1/3 of articles. When Table 3 is examined, it can be seen that there are 16 journals clustered in the first region.

The Most Influential Authors

The Web of Science database contains research on STEM in education from 5,458 academics. Table 4 provides information on the 20 authors who published the most on the subject, including details on publication years, citation counts, and index scores. Guzey S.S. (NP=12) is the author who has published the most on the subject. This author also has the highest g_index score (g_index=12). Capraro M.M. (h_index=7) is one of the authors with the highest h_index score and the most cited author (TC=286).

It is seen that Gilead T. and Wang X. are not cited locally. Henderson C. (h_index = 7, g_index=9, TC=249), English L.D. (h_index = 7, g_index=8, TC=232), Bers M.U. (h_index = 6, g_index=6, TC=250) and Johnson C.C. (h_index = 4, g_index=6, TC=281) stand out as other prominent authors. Some authors are not included in this table, which is presented considering the citations at the global level but are highly ranked at the local level. These authors are Maltese A.V. (LC=112), Tai R.H. (LC=111) King B. (LC=70), Riegle-Crumb C. (LC=67) and Corlu M.S. (LC=66). Figure 2 depicts the distribution of the authors' research by year.

Table 4. The Most Influential Authors

Author	*h*_index	*g*_index	*TC	*LC	*NP	*PY_Start
Guzey S.S.	5	12	155	52	12	2014
Roehrig G.H.	6	11	189	34	11	2012
Capraro R.M.	7	9	176	61	9	2014
Gottfried M.A.	3	5	39	36	9	
Henderson C.	7	9	249	39	9	2013
Moore T.J.	5	9	189	37	9	2012
Capraro M.M.	7	8	286	61	8	2014
English L.D.	7	8	232	89	8	2012
Dare E.A.	5	7	110	62	7	2016
Gilead T.	4	7	50	0	7	2009
Lin K.Y.	6	7	87	15	7	
Micari M.	5	7	88	9	7	2010
Wang X.	5	7	128	0	7	2013
Archer L.	4	6	93	11	6	2017
Bers M.U.	6	6	250	1	6	2013
Borrego M.	3	6	206	33	6	2013
Dori Y.J.	4	6	63	7	6	2018
Johnson C.C.	4	6	281	3	6	
Kelly A.M.	4	5	29	6	6	2013
Kezar A.	5	6	84	24	6	2017

*TC= Total Citation, *LC=Local Citation, *NP=Number of Publications, *PY_Start=Publication Year Start

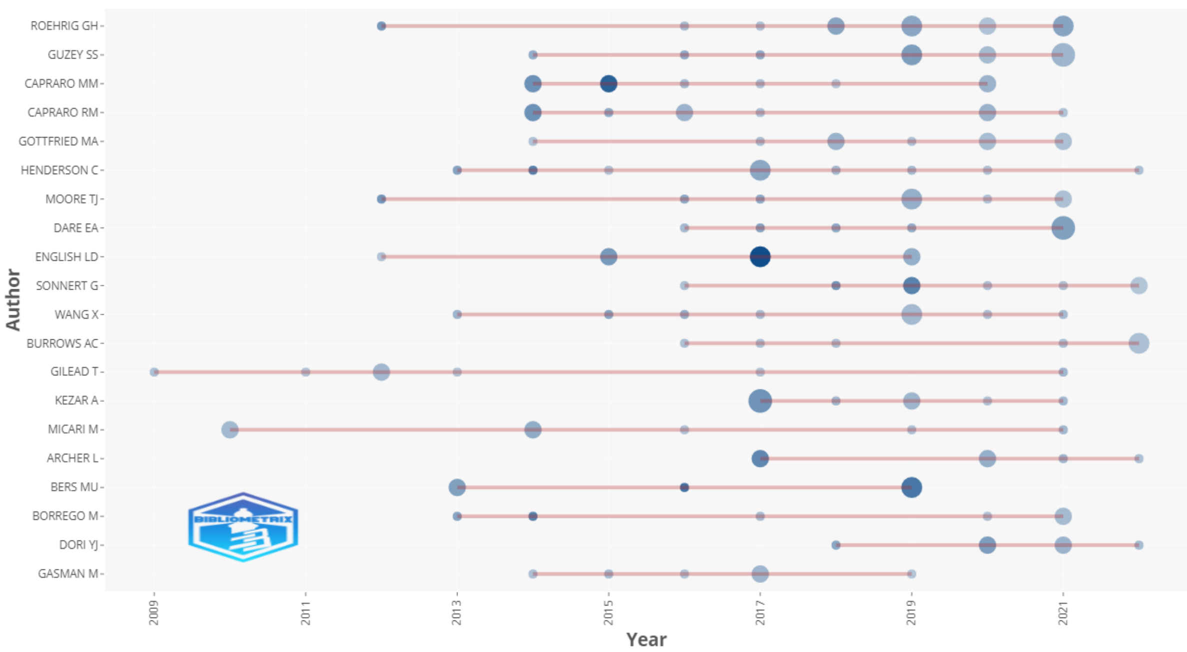

Figure 2. Top Authors' Production over Time

Gilead T. was spotted studying about STEM education in 2000s. It is noticeable that there are now more authors publishing studies from years beyond 2013. Especially authors produced more articles in 2017, 2019 and 2021 than other years. The research by Henderson C., Sonnert G., Burrows A.C., Archer L., and Dori Y.J. distinguished after that done in 2022 when this study was carried out.

The Most Influential Countries and Universities

Table 5 provides the 20 universities with the most publications and articles. A total of 1380 publications on the topic have been written and published by these 20 universities.

Table 5. The Most İnfluential Universities

Affiliations	**Articles**
Purdue Univ.	151
Univ. Wisconsin	94
Texas Aandm Univ.	91
Vanderbilt Univ.	80
Natl Taiwan Normal Univ.	78
Michigan State Univ.	77
Arizona State Univ.	76
Univ. Texas Austin	76
Univ. Minnesota	69
Univ. Michigan	66
Univ. Colorado	64
Univ. Georgia	63
Northwestern Univ.	60
North Carolina State Univ.	59
Univ. Calif Los Angeles	58
Univ. Illinois	57
Univ. Virginia	57
Univ. Nebraska	53
Curtin Univ.	51
Ohio state Univ.	50

The university that publishes the most is Purdue University, with 151 articles. The University of Wisconsin follows this university with 94 articles and Texas Aandm University with 91 articles. Notably, 19 of the 20 universities on the list are from the USA. Natl Taiwan Normal University is the other university in the top 20 with 78 articles. Table 6 displays the essential information on the number of publications depending on the country, the number of responsible authors, the status of the study from one or more countries, and the number of citations.

The USA has the highest number of publications (ArtN=5.589). This country is followed by China (ArtN=541), the United Kingdom (ArtN=501), and Australia (ArtN= 476). USA also has the highest number of co-authored articles (CAAN=1,755), national articles (SCP=1,488), international articles (MCP=87), and citations (19,857). It is seen that the Netherlands is ahead in the average number of citations per article (AAC=13.50). However, among the countries not included in this list, Serbia (AAC=59.20), Cyprus (AAC=28.12), Norway (AAC=22.65), and Belgium (AAC=16.80) have high average citation numbers per article draws attention.

Table 6. The Most Influential Countries

Country	*ArtN	*CAAN	Freq	*SCP	*MCP	*MCP_Ratio	*TC	*AAC
USA	5.589	1.575	0.519	1.488	87	0.05	19.857	12.60
United Kingdom	501	181	0.059	154	27	0.14	1.516	8.37
Australia	476	161	0.053	138	23	0.14	1.362	8.46
China	541	148	0.048	106	42	0.28	1.011	6.83
Turkey	357	126	0.041	116	10	0.07	649	5.15
Spain	268	100	0.033	87	13	0.13	489	4.89
Canada	216	68	0.022	57	11	0.16	477	7.01
Germany	177	52	0.017	38	14	0.26	449	8.63
Israel	150	48	0.015	41	7	0.14	464	9.66
Netherlands	110	34	0.011	21	13	0.38	459	13.50
Malaysia	100	31	0.010	26	5	0.16	184	5.93
Ireland	93	28	0.009	15	13	0.46	185	6.60
South Africa	79	27	0.008	25	2	0.07	142	5.25
Denmark	73	25	0.008	21	4	0.16	216	8.65
Greece	71	22	0.007	19	3	0.13	225	3.86
Italy	69	22	0.007	18	4	0.18	216	2.04
Sweden	59	22	0.007	14	8	0.36	85	5.68
Korea	63	20	0.006	10	10	0.50	237	11.85
Finland	51	18	0.005	10	8	0.44	118	6.55
Russia	92	18	0.005	17	1	0.05	53	2.94

*ArtN= Article Number, *CAAN= Corresponding Author Article Number, *SCP=Single Country Publication, *MCP=Multiple Country Publication, *TCN= Total Citations Number, *AAC= Average Article Citation

Citation Status

Table 7 displays data on the number of citations of the publications at the global and local levels. The article by Blickenstaff, "Women and Science Careers: Leaky Pipeline or Gender Filter?," which appeared in Gender and Education in 2005 (TC=808), has received the most citations worldwide. It is seen that this article has not been cited locally. Six articles received no local citations. The paper by Maltese, "Pipeline Persistence: Examining the Association of Educational Experiences with Earned Degrees in STEM Among U.S. Students," published in 2019, has the highest local citation rate (LC/GC (%) =27.34). This article is also the second most cited article.

Table 7. Citations of the Publications

Document	DOI	Year	*LC	*TC	TC per Year	LC/TC Ratio (%)
Blickenstaff İ.C., 2005, Gend. Educ.	10.1080/09540250500145072	2005	0	637	35.38	0.00
Maltese A.V., 2011, Sci. Educ..	10.1002/sce.20441	2011	111	406	33.83	27.34
Weintrop D., 2016, J. Sci. Educ. Technol.	10.1007/s10956-015-9581-5	2016	39	379	54.14	10.29
PotkonJ.ak v, 2016, Comput. & Educ.	10.1016/j.compedu.2016.02.002	2016	5	292	41.71	1.71
Bang M., 2010, Sci. Educ.	10.1002/sce.20392	2010	26	238	18.30	10.92
Griffith A.L., 2010, Econ. Educ. Rev.	10.1016/j.econedurev.2010.06.010	2010	38	234	18.00	16.24
Espinosa L.L., 2011, Harv. Educ. Rev.	10.17763/haer.81.2.92315ww157656k3u	2011	0	229	19.08	0.00
Eagan M.K., 2013, Am. Educ. Res. J.	10.3102/0002831213482038	2013	22	228	22.80	9.65
Crismond D.P., 2012, J. Eng. Educ.	10.1002/j.2168-9830.2012.tb01127.x	2012	29	224	20.36	12.95
Breiner J. M., 2012, Sch. Sci. Math.	10.1111/j.1949-8594.2011.00109.x	2012	0	223	20.27	0.00
Crisp G., 2009, Am. Educ. Res. J.	10.3102/0002831209349460	2009	55	220	15.71	25.00
Lindgren R., 2016, Comput. & Educ.	10.1016/j.compedu.2016.01.001	2016	7	192	27.42	3.65
Sengupta P., 2013, Educ. Inf. Technol.	10.1007/s10639-012-9240-x	2013	24	182	18.20	13.19
Young M., 2013, Rev. Educ.	10.1002/rev3.3017	2013	0	161	16.10	0.00
Riegle-crumb C., 2010, Educ. researcher	10.3102/0013189X10391657	2010	33	159	12.23	20.75
Riegle-crumb C., 2012, Am. Educ. Res. J.	10.3102/0002831211435229	2012	26	155	14.09	16.77
Kyriakides L., 2009, Teach. Educ.	10.1016/j.tate.2008.06.001	2009	0	151	10.78	0.00
Thiry H., 2011, J. High. Educ.	10.1080/00221546.2011.11777209	2011	12	148	12.33	8.11
Ong M., 2018, J. Res. Sci. teach.	10.1002/tea.21417	2018	32	133	26.60	24.06
Tseng K.H., 2013, Int. J. Technol. Des. Educ.	10.1007/s10798-011-9160-x	2013	0	128	12.80	0.00

Keywords and Trend Topics

Most Frequent Words analysis was performed on the obtained articles about STEM education among the author keywords. The word cloud for author keywords is shown in Figure 3.

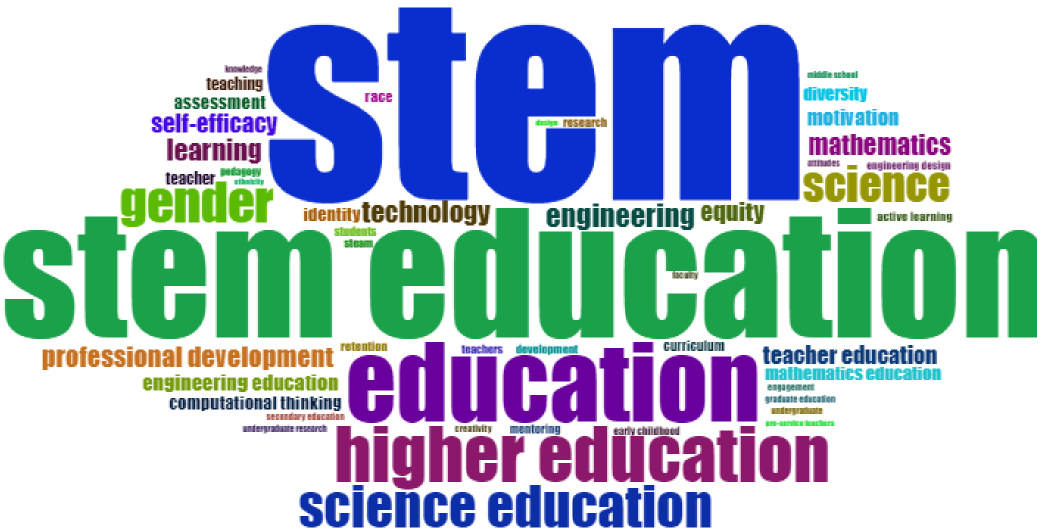

Figure 3. Author Keywords' Word Cloud

The most used keywords by the authors are STEM (F=735) and STEM Education (F=453). These keywords are followed by the terms "Education" (F=276), "Higher Education" (F=195), "Science Education" (F=151), "Gender" (145), and "Science" (125). Frequently used keywords "Self-efficacy" (F=68), "Motivation" (F=58), "Assessment" (F=51), and "Computational Thinking" (F=50) have the potential to offer an idea about the variables used by researchers. Figure 4 illustrates author keywords' year-by-year trends.

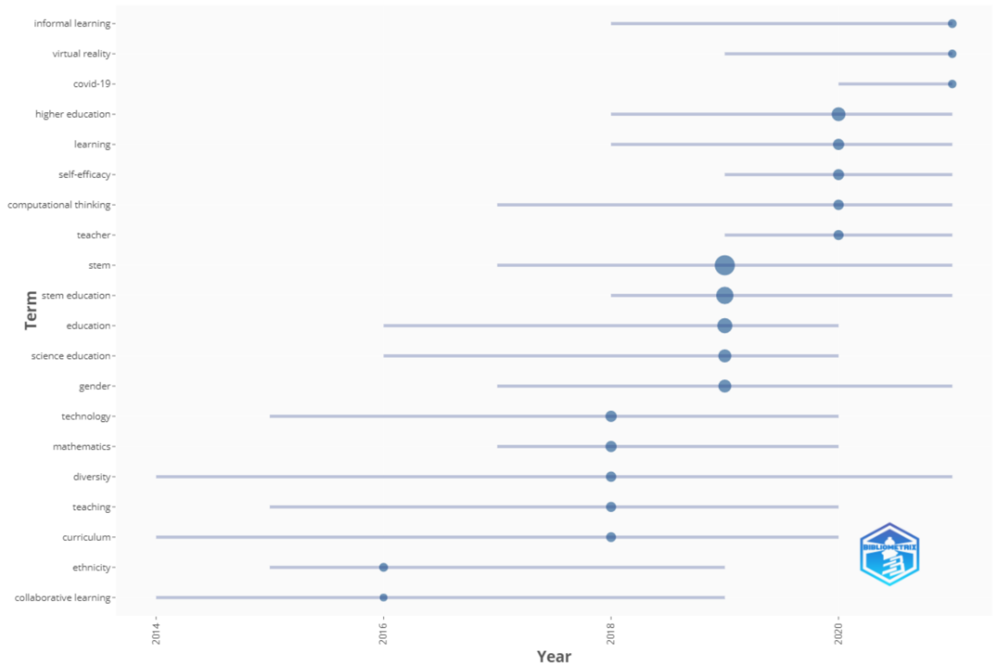

Figure 4. Trend Topics

When we analyze the figure, we can see that prior research on mathematics, ethnicity, and collaborative learning was gradually replaced with studies on informal learning, virtual reality, COVID 19, STEM, and STEM Education. It is understood from the graph that the COVID19 pandemic is also effective in the field of STEM education. Especially after 2020, it is seen that self-efficacy, learning and computational thinking variables come to the fore as dependent variables.

Cluster by Authors Coupling

On the papers in this study, a cluster analysis was run. Table 9 lists the author's key phrases, the number of clusters, their centricity, and the impact of each cluster. According to the results of the cluster analysis, four clusters were formed. "STEM" appears to be included in all clusters. "STEM Education" also found a place in three clusters. The emergence of STEM identity and gender concepts in cluster 4 has revealed their importance in the field of STEM education. Using network analysis, Figure 5 depicts the relationships between the authors. The algorithm grouped each distinct hue by determining the relationship between the authors. While performing the cluster analysis, references, global citation scores, and author keywords were chosen, and the minimum number of clusters was taken as 5.

Table 8. Cluster Analysis Results

Label	Group	Freq.	Centrality	Impact
Stem Stem education Education	1	103	0.42	1.99
Stem Stem education Equity	2	54	0.37	1.93
Stem education Stem Higher education	3	44	0.29	2.19
Stem Identity Gender	4	41	0.45	1.84

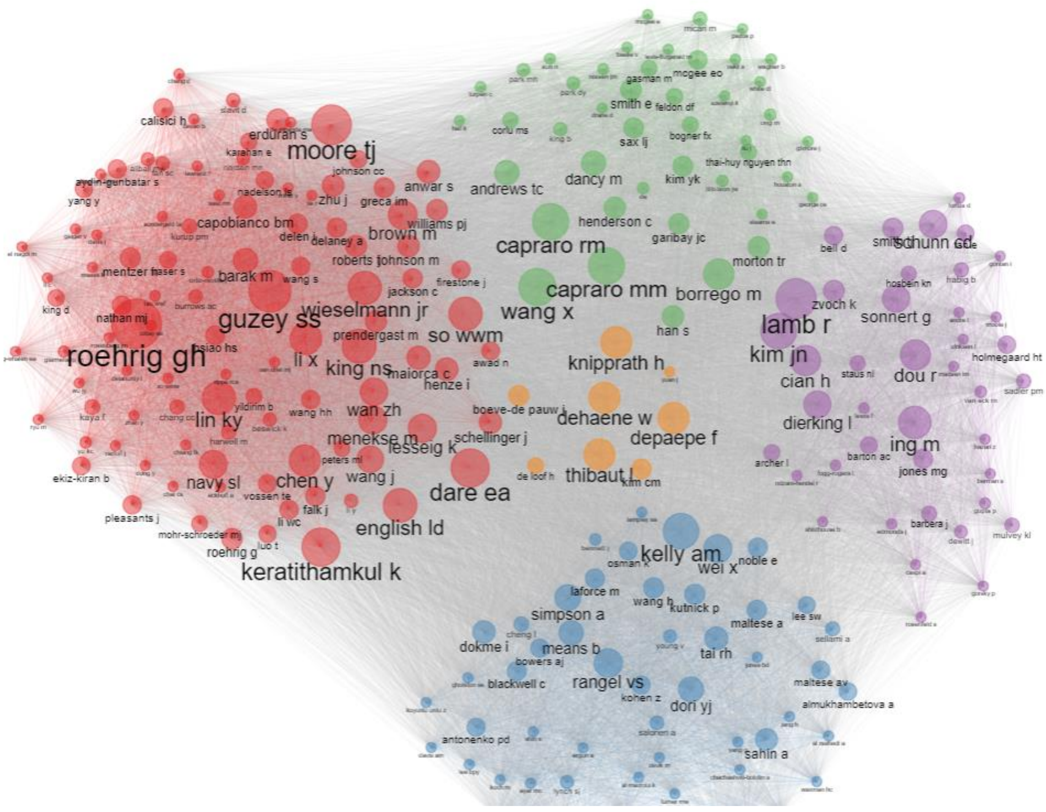

Figure 5. Relationships between the Authors

Capraro R.M., Capraro M.M., and Wang X are the most productive authors in the green cluster when the author network is evaluated using the Rstudio tool. Guzeys S.S., Roehrig G.H., and Moore T.J. stand out in the red cluster. Lamb R and Kim J.N. are the most influential authors in the blue cluster. Kelly A.M. and Rangel V.S. show out in the purple cluster. When the Authors' measured network analysis is reviewed, it is discovered that they are organized into five distinct cluster

Discussion

In this study, bibliometric analyzes of scientific research published in the field of STEM education were carried out. The Web of Science database was searched with the keywords "STEM" AND "EDUCATION."In the bibliometric analysis, 3046 studies were published in the article type from 1992 to 2022. The number of studies included in the research by years and the frequency values for citation analysis were determined. In addition, the articles and authors included in the data set of the study and having the highest number of citations in the field were determined.

The International Journal of Stem Education is the most widely published. Journal of Science Education and Technology received the most citations. Computers & Education and the Journal of Engineering are other notable journals. According to Bradford's Law, there were 16 journals clustered in the first region. In his study in 2019, Özkaya found the most influential journals on the subject as the Journal of Research in Science Teaching and Technology and The Journal of Educational Research. Yu et al., in their study in 2016, stated that the most influential journals are the International Journal of Science Education, Journal of Science Education and Technology, Journal of Engineering Education, Teachers College Record, and Research in Higher Education.

Guzey S.S. is the author with the most publications on the subject. Capraro M.M. most cited author. Henderson C., English L.D., Bers M.U., and Johnson C.C. stand out as other prominent writers. Maltese A.V., Tai R.H., King B., Riegle-Crumb C., and Corlu M.S. He is among the most cited authors locally. In the early 2000s, Gilead T. was observed engaging in research. More authors are currently posting works from years beyond 2013. The research conducted in 2022, when this study was conducted, is distinguished from that by Henderson C., Sonnert G., Burrows A.C., Archer L., and Dori Y.J.

The university that publishes the most is Purdue University. This university is followed by the University of Wisconsin and Texas Aandm University. Notably, 19 of the 20 universities on the list are from the USA. Natl Taiwan Normal University is the other university in the top 20.

The USA is the country with the highest number of publications. This country is followed by China, the United Kingdom, and Australia. The USA also has the highest number of articles with responsible authors, national articles, international articles, and citations. It is seen that the Netherlands is ahead in the average number of citations per article. However, it is noteworthy that Serbia, Cyprus, Norway, and Belgium, which are not included in this list, have high average citation counts per article. In another bibliometric analysis in the related field article, the most influential countries were the USA, the United Kingdom, the Netherlands, Australia, and Spain (Yu et al., 2016). Özkaya mentioned the USA and the United Kingdom as the most influential countries in her study in 2019. These findings are also consistent with our results.

The paper by Blickenstaff titled "Women and Science Careers: Leaky Pipeline or Gender Filter?," which was published in Gender and Education in 2005, has been cited the most all around the world. The research by Maltese entitled "Pipeline Persistence: Examining the Association of Educational Experiences with Earned Degrees in STEM Among U.S. Students," which was published in 2019, had the highest local citation rate.

The most commonly used keywords by the authors are “STEM” and “STEM Education.” These keywords are followed by the terms “Education,” “Higher Education,” “Science Education,” “Gender,” and “Science.” Among the frequently used keywords, “Self-efficacy,” “Motivation,” “Assessment,” and “Computational Thinking” offer ideas in terms of the variables used by the researchers. Prior research on mathematics, ethnicity, and collaborative learning has increasingly been supplanted by studies on informal learning, virtual reality, COVID 19, STEM, and STEM Education. When other bibliometric analyses in the field are examined, it can be seen that the keyword analysis results are consistent with the words in this study (Aseffa & Rorissa, 2013; Özkaya, 2019; Yu et al., 2016).

According to the results of cluster analysis, four clusters were formed. The term "STEM" appears to be present in all clusters. "STEM Education" was also included in three clusters. When the author network is examined, Capraro R.M., Capraro M.M., and Wang X are the most prolific writers in the green cluster. In the red cluster, Guzeys S.S., Roehrig G.H., and Moore T.J. stand out. The most productive writers in the blue cluster are Lamb R and Kim J.N. In the purple cluster, Kelly A.M. and Rangel V.S. stand out.

Conclusion

We provided important findings for researchers in this bibliometric analysis study, which studied STEM education and examined various aspects of all reviewed articles in Web of Science. In general, the increase in the number of people/organizations working on STEM education indicates that the number of national and international studies in STEM education will gradually increase, and STEM education will be more involved in educational programs. We can see American universities, researchers and journals have a important role in this area. Thus, Bradford's Law results confirmed this conclusion. In addition, the prominent concepts as the output of STEM education are computational thinking, equity, diversity, motivation, engagement, and self-efficacy.

It is recommended that researchers working on STEM education pay attention to publications that have had a citation explosion, words with the highest frequency and centrality values, and words that have had a citation explosion. It seems that these concepts will often come across shortly.

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