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Bibliometric analysis of the studies in the field of mathematics education

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The purpose of this study is to perform bibliometric analysis of the scientific researches published in mathematics education subject area between 1980 and 2018, to find out the general layout of the scientific knowledge and communication structure of the field using an objective method, driven from the data. The publications were analyzed according to publication year, type of publication, language of publication, title of publication, name of the author, country of the author and number of citations taken from the sources scanned in Web of Science (WoS) Core Collection database; structural and temporal analysis of various networks, such as collaboration networks and author collaborations were performed. In addition, a word analysis was also conducted in the study to determine the concepts used in the researches published in mathematics education area and covered in the data set. It was found that the publications involving mathematics education increased from 1980 to 2018. The review of the countries according to the number of studies that they have performed in the field revealed that the most productive countries are United States, England and Turkey. Regarding the centrality of the countries in the network, the countries that are located at the center of the network were found to be England, US and Spain, respectively. Regarding the ranking of the countries according to the number of citations taken for the scientific works that they have performed in mathematics education area, it was found that US, Turkey and Malaysia had the highest number of citation bursts. Regarding the ranking of the works according to title, the topics that have been mostly worked on are elementary mathematics classroom, teacher education and achievement gap. The words that are mostly used in mathematics education research area were mathematics, education, student and achievement, respectively.

Key words: Social network analysis, bibliometric analysis, mathematics education, scientific knowledge, scientific communication.

INTRODUCTION

In today's world, which is dominated by technology, many national and international scientific researches, reviews and studies are performed in mathematics education area, as in the other disciplines. The variations that have occurred in the content of the courses based on the developments in science revealed different views about the needs of a developing society and how mathematics instruction should be done to achieve a

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more effective mathematics education. Analyzing the trend of recent researches performed in mathematics education will guide the researchers and educators for scientific debates and queries, as well as illuminating short, middle and long-term studies (Milli, 2018).

The researches show that the achievements in mathematics education can be enhanced through new approaches. A student-centered mathematics education approach, performed in an environment where students can express their thoughts freely, develop their reflection strategy, and well-connected with daily life is expected to contribute to rising individuals who are capable of thinking mathematically and solving problems (Umay, 1996).

As a natural result of the changes and regulations realized in mathematics education programs, changes occur in the roles of teachers and students in education. New programs outline the roles of the teachers not only as planning activities, but also as "questioning, listening, guiding, motivating and making students ask questions, think and discuss"; whereas they define students as individuals who are capable of "asking questions, querying, developing their own problems and solving them, thinking, discussing and working together". The changes and improvements in the curriculums help to proceed on enhancing the quality of the education and solving various problems that are present in the education system (Arslan and Özpınar, 2008).

Social network analysis is an inter-disciplinary research area built on various disciplines, including sociology, anthropology, statistic, and mathematics (Van and Vermunt, 2006). With the improvements in the content of social network analysis (foundation based on 1960s), in recent years, it became one of the working areas often talked about. Social network analysis aims to explain, visualize and understand the network structure obtained from the relationships among individuals through statistical modelling. As in the other disciplines, social network analysis is widely used in education as well (Carolan, 2013; Scott, 2017). The most significant feature of this approach focuses on the relationships between individuals and social units, rather than these entities themselves (Martino and Spoto, 2006). Social network analysis is also used to determine the significant actors in a research community through the visualization of collaboration and common citation networks, in addition to identify information networks that are effective on the development of the research area (Yüncü and Karagöz, 2013). The visualization of social networks is quite important in terms of understanding social network data and interpreting analysis results. Most of the software developed for this purpose use different modules for the visualization of the network. Bibliometric analysis method is one of the tools used to see overall picture of a field, to analyze the scientific works published in this area and to interpret the results both statistically

and visually.

Bibliometrics involves the quantitative analysis of certain characteristics of the publications or documents, including author, subject, publication information, cited sources, etc. It is possible to investigate how scientific communication process occurs using obtained bibliometric data (Güzeller and Çeliker, 2018). Bibliometric studies allow the identification of the trends in a certain field by quantifying the literature in this area (Kasemodel et al., 2016). In bibliometric researches, the works are analyzed according to certain characteristics and various findings are obtained (Al and Coştur, 2007). Citation analysis performed in bibliometric studies allows the assessment of the qualities of scientific publications. Most important data sources of bibliometric researches are international scientific citation indexes, including Science Citation Index (SCI), Social Science Citation Index (SSCI) and Art & Humanities Citation Index (A&HCI), which are being accessed through Web of Science (WoS) Core Collection database. WoS makes significant contributions to bibliometric works as a database hosting bibliometric data concerning the publications scanned in these indexes (Güzeller and Çeliker, 2017). Within the scope of the study, we attempted to review all works concerning mathematics education, published in WoS database between 1980-2018; to identify the authors and journals that have performed important works in mathematics education area from past to present; and to reveal popular topics according to years. In addition, the effect of country variable on the performed works was investigated by identifying the countries of the researchers who have worked on mathematics education area.

Problem statement of the research

What are the authors, journals, countries and topics that have been effective in mathematics education field between 1980-2018?

The following sub-problems were also addressed within the scope of the study:

1. Regarding the number of academic works realized in mathematics education area, what are the most productive countries in terms of total number of publications?
2. Regarding the number of citations taken from the scientific works, what are the countries with the highest citation bursts, that is attracting an extraordinary degree of attention from its scientific community?
3. What are the works that get the highest number of citations from the studies included in the data set?
4. What are the most frequently used keywords in the studies published in mathematics education research

area?
5. What are the concepts that are most frequently used in the studies published in mathematics education research area?

Bibliometric researches conducted in mathematics education area

Regarding the bibliometric studies in the literature, there are numerous national and international studies assessing the articles published in the journals, master thesis, papers presented in the congress and symposiums. On the other hand, it was observed that there are few bibliometric studies performed in mathematics education area.

In his thesis, Yücedağ (2010) has analyzed 390 postgraduate theses performed in mathematics education area, and 153 articles published in 4 Turkey-centered journals between 2000-2009. As a result of the analysis, the terms mostly used in research titles were found to be "instruction methods" for the theses and "affective dimension" for the articles. The subtitles that have been used most in both theses and articles were found to be "attitude" and "problem solving", whereas the titles that have been least worked on were "motivation" and "habit". The methods than have been mostly used in the theses were experimental research, content analysis and literature review, whereas collection was the least used method. The methods mostly used in the articles were respectively experimental, literature review and content analysis, whereas book review was the least used method. The researcher has stated that geometry and algebra were mostly studied topics in theses, whereas articles mostly focused on algebra.

In his thesis, İlhan (2011) worked on 124 national postgraduate theses, 219 national and 356 international articles published between 2005-2009 in mathematics education area and he revealed their distributions thematically, methodologically and in terms of statistical analysis techniques. A total of 343 national and 356 international works have been analyzed using Academic Publication Assessment Form, developed for this purpose. Thematically; a tendency towards cognitive area was observed in international studies, whereas works concerning instruction strategies, teaching methods and techniques, along with achievement were more popular in national studies. Methodically; international researches were concentrated on literature reviews and studies concerning teachers, in national studies experimental researches and studies having samples from elementary education 2nd level students were more prevalent. In terms of statistical techniques: descriptive statistics, t-test, ANOVA were the techniques frequently used in both groups. Constant comparison, Kruskal Wallis-H, regression, discourse analysis and multiple regression were other techniques preferred in international studies.

In his paper, Yılmaz (2011) has analyzed 82 articles published in Elementary and Secondary Mathematics Education Area, in Hacettepe University Education Faculty Journal, from 1988-2010. In his work, the articles were classified according to their sample compositions, divided into certain categories for each sample, the themes were formed and combined with other samples. The findings were obtained after performing content analysis on the articles. As a result of the research it was found that: numerous researches have been conducted in teaching-learning area; these researches have been mostly concentrated on active mathematics learning; when analyzed a little more specifically, it was found that many factors, such as method, technique, and environment have affected this fact and they have been affected by this fact. In addition, it was found that researches have been conducted in many areas, including mathematic-language, achievement, nature of mathematics, gender, cognitive and inherent factors and these works have moved mathematics education one step ahead.

Yaşar and Papatğa (2015) have analyzed 50 postgraduate theses concerning elementary school's mathematics courses performed from 2002-2012, through qualitative research method. Data were collected via document review and the theses were analyzed according to: the postgraduate level that they were performed, university and discipline, title of the advisors who undertook execution responsibility, year of preparation, class level of the primary school where the study was realized, selected subject area, selected topic, research methods, data collection techniques and data analysis methods. Research data were analyzed using content analysis. As a result of the research it was found that; most of the prepared theses were postgraduate, most of the theses were performed in 2010 and 2011, at 5th grade level, mostly assistant professors participated as advisor, mostly performed in algebra subject area, quantitative research method was frequently used, achievements test was mostly used as data collection technique, and t-test was employed in quantitative data analysis.

Çiftçi et al. (2016) aimed to perform citation analysis to the scientific journals published in educational science field in Turkey and determine their impact factors. For this purpose, a comprehensive citation analysis was performed with over 7,681 articles, published in 32 scientific journals with reviewer; then impact factors of each journals were identified. SPSS, NVivo, Excel and ESOGU-BAAP software, developed for the research, were used in the bibliometric and citation analysis of the articles. Regarding the articles analyzed within the scope of the research, top three most cited journals were found to be (i) Hacettepe University Education Faculty Journal, (ii) Educational Sciences in Theory and Practice and (iii)

Ankara University Educational Sciences Faculty Journal. Regarding 2014's impact factor coefficient of the journals covered within the scope of the research, the journals with the highest impact factor coefficient were found to be (i) Educational Sciences in Theory and Practice, (ii) Educational Management in in Theory and Practice and (iii) Theoretical Education Science Journal.

METHODOLOGY

In this study, scientific studies published in mathematics education area and included in Web of Science (WoS) database were analyzed using bibliometric analysis method. In this scope, this study was performed within the frame of descriptive analysis, using document review method (Güzeller and Çeliker, 2018). Since the study aims to describe current situation, it can be accepted as a study of scanning model type (Franken et al., 2012).

Data collection process

In this regard, Web of Science database was scanned for "mathematics education" keywords to obtain the data of the research. As a result of the scan performed in Web of Science in the time interval set as 1980-2018, a total of 9,841 scientific researches were found.

14,831 scientific records were reached in the period of 1980-2018 in mathematics education in the Web of Science. As some of these records contain studies related to different disciplines, the records are limited to the topics of education, educational research, education scientific disciplines, and special education. In this context, 9,941 scientific records were provided which provide the inclusion criteria.

Data analysis

Citespace II, which is a social network analysis software, was used to determine the concepts used in mathematics education area; to find out the countries of the authors who led the researches; to identify the authors, works and the journals in which these works were published; and to visualize the relationships among them. Citespace II is a Java application used to visualize and analyze the trends and changes occurring in a scientific area or topic (Chen, 2006). This software performs structural and temporal analysis of various networks obtained from scientific publications, such as collaboration networks, author associations (Synnestvedt et al., 2005).

In order to start the analysis, all bibliometric data, including author name, title, source of the documents, publication year, title of publications, number of citations, citation and type of the article were collected in electronic format and saved as text document (with .txt extension). Data were downloaded as batch of 500 files in .txt format and loaded to Citespace II software, which united these files and analyzed as a single data file. Data files to be analyzed were introduced into the program; the time period was defined; "cited references", "cited author" and "cited journal" options were activated. The results obtained from Citespace II software were displayed in two different forms (time zone and cluster view). In time zone view, the change of common citations over time was visualized, whereas in cluster view, cluster divisions obtained from common citations in the defined time zone were visualized. Analysis results were separately reported in the form of cluster view and time zone view. In Citespace program, the names of critical authors, journals and countries are represented by circle, line or color. The circle around the author, journal or country indicates the citation history of a particular reference, whereas the thickness of the circle shows the number of citations over a defined time period. Bigger circles indicate higher number of references. The line between two circles indicates common reference sources present in both citations. The thickness of this line shows the strength of the common citation, whereas its color indicates the time of the common citation (Liu and Shen, 2013).

During the analysis, the contributions of the authors connected with different countries were computed separately to determine countries' overall productivity. In the cases where the authors stated two different institutions and countries due to performing researches in two different institutions, located in different countries, the country stated in the first place was included in the analysis unit. While performing the analysis, if a publication contained two or more authors from the same country, the country was counted once.

FINDINGS

Distribution of publications according to years

As a result of the scan performed with math education/mathematics education keywords, 14.831 scientific records were found to be published from 1980-2018. In order to prevent the same study to be present twice in the scans performed with both keywords and to eliminate the possibility of including the same study twice in the analysis, data were downloaded from Web of Science in excel format. It is possible to download various information from Web of Science in excel format, such as the titles of the works that will be used in the data, their authors, publication years, the journals in which they were published, volume number and pages. In this regard, the titles of the works obtained from both keyword scans were alphabetically sorted in excel and one of the studies found to be identical were excluded from the analysis. 9.841 individual studies were found and their duplications were removed from the data. In other words, double-counted studies were counted once while calculating the number of publications. In addition, one of the double-counted studies was removed while loading them to Citespace software; therefore country, common citation and word analysis remained unaffected from double-counted studies.

Since some of these records covered the studies from different disciplines/themes, for the sake of the research objective, the records were limited with education, educational research, education scientific disciplines, and special education themes. Within this scope, the analyses were performed on 9.841 scientific records that fulfilled inclusion criteria (Figure 1).

Regarding the distribution of the publication according to defined time periods, it is seen that the number of publications increased in each period. It can be seen that the highest number of publications was realized between
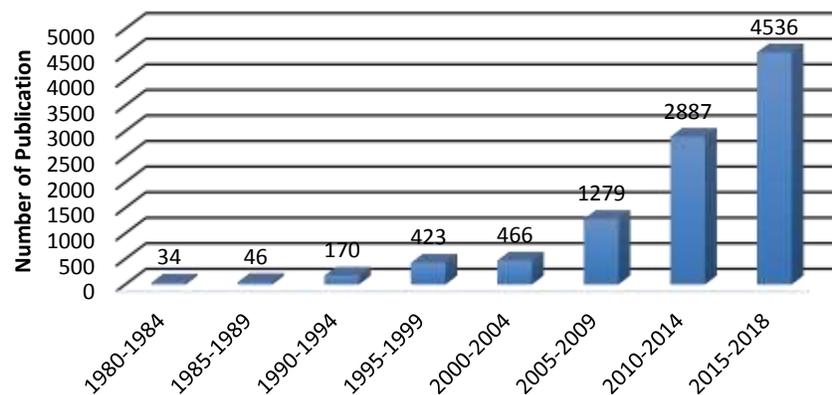
Figure 1. Distribution of the Publications according to time periods.

Table 1. Frequency values and centrality degrees of the countries.

Number of citations	Countries	Cluster #	Centrality	Countries	Cluster #
4073	USA	0	0.31	ENGLAND	4
569	England	4	0.30	USA	0
520	Turkey	0	0.17	SPAIN	1
467	Spain	1	0.14	NETHERLANDS	3
405	Australia	0	0.09	GERMANY	2
379	Germany	2	0.08	FRANCE	2
337	Canada	2	0.07	AUSTRALIA	0
258	Netherlands	3	0.05	CHILE	1
216	South Africa	2	0.05	BRAZIL	1
198	Peoples R China	0	0.05	SWEDEN	2

2015-2018 (46.1%) (n=4,536). The publications made in 2010 and after constitute 75.4% of the whole publications. Since this result covers the period that our study is being performed, it can be said that the number of publications in 2018 is expected to increase.

Countries that have contributed to the field

A network analysis was performed to determine the countries of the authors that have made the biggest contributions to mathematics education area in terms of scientific work. The network obtained as the result of the analysis consists of 78 nodes (countries) and 393 connections (relationship between countries). The network was divided into 14 clusters; its density was calculated as 0.13, where network density shows the ratio of the connections used in a network and the number of potential connections (Al and Doğan, 2012: 354). Q modularity value of the network was found to be 0.24, where Q modularity takes a value between 0-1 and

the values closer to 1 signify closer relations and connections within the cluster. Usually Q modularity values between 0.4-0.8 are accepted as the indicator of a good clustering. Mean silhouette value was 0.17, where mean silhouette value takes a value between -1 and 1 and the values close to 1 signify that the factors in the network are consistent and similar (Güzeller and Çeliker, 2018; Li et al., 2017; Zhang et al., 2015).

The most productive 10 countries of the network are shown in Table 1, with their frequencies. In addition, top 10 countries having the highest centrality values are also displayed in Table 1. The countries having 100 or more frequencies are included in the network and the purple circle in the network indicates the countries with high centrality (Figure 2).

Regarding the number of publications of the countries in mathematics education area, US was found to be the most productive country with 4,073 academic works, whereas England is the second most productive country with 569 works and Turkey is the third most productive country with 520 works. While determining country

Figure 2. Countries that have contributed to the field.

Table 2. Citation Burst Values of the Countries.

Countries	Strength	Begin	End	1980-2018
USA	110.64	1980	2004	
TURKEY	13.50	2012	2013	
MALAYSIA	12.11	2010	2014	
FRANCE	9.84	2008	2011	
COLOMBIA	7.74	2015	2016	
CHILE	7.21	2016	2018	
CYPRUS	7.12	2008	2010	
ITALY	6.88	2008	2011	
DENMARK	6.13	2010	2011	
BRAZIL	5.78	2009	2010	

productivity, if a publication contained two or more authors from the same country, the country was counted once.

Regarding the centrality of the countries, it can be seen that the most central countries in the network are England (0.31), USA (0.30) and Spain (0.17). It can be said that these countries play an important role in the establishment of scientific communication in mathematics education area and they serve as a bridge.

Regarding the citation bursts calculated according to the number of citations that countries received from the scientific works that realized, the presence of citation bursts were detected for 22 countries and it can be seen that the works performed by the authors of USA have the highest value (110.64) (Table 2). Accordingly, it can be said that from 1980-2004, authors from USA have guided the works that have been performed in the field and they have made significant contributions to the development of the field. Another result is that authors from Chili are frequently referred by the recent works performed in the field.

Publication's Common Citation Network

A network analysis was conducted based on the bibliographies of the studies included in the data set in order to determine the reference sources that were

Table 3. Frequencies of Citation Sources.

CC	References	Year	First Author	Cluster #
161	Content knowledge for teaching: What makes it special?	2008	Loewenberg Ball	1
145	Common Core State Standards for Mathematics (CCSSM).	2010	Common Core State Standards Initiative	1
110	Principles and standards for school mathematics	2000	National Council of Teachers of Mathematics	6
103	Visible learning: A synthesis of over 800 meta-analyses relating to achievement	2008	Hattie J.	1
95	Teachers' mathematical knowledge, cognitive activation in the classroom and student progress	2010	Baumert, J.	1
83	Active learning increases student performance in science, engineering and mathematics	2014	Freeman, S	12
83	Foundations for success: The final report of the National Mathematics Advisory Panel	2008	National Mathematics Advisory Panel	4
77	Effects of teachers' mathematical knowledge for teaching on student achievement	2005	Hill H. C	4
68	Next generation science standards: For states, by states.	2013	National Research Council	1
65	Common core state standards	2010	National Governors Association	1

CC, Citation Counts.

mostly cited in mathematics education area. As a result of the analysis, a network consisting of 1610 nodes (publication), 4395 connections (relationships between publications) and divided into 321 clusters was obtained. The network density was calculated as 0.0034. Its Q modularity value is 0.84, mean silhouette value is 0.26. The colors in the network represent the distribution according to years, whereas red circles show citation bursts. The reference sources included in the network are the ones having 50 or more frequencies and they are shown with green. The topic clusters by references are shown with black. Top 10 sources with highest frequencies are shown in Table 3.

The work that got the highest number of citations from the studies included in the data set is the article titled as "*Content knowledge for teaching: What makes it special?*" (n=161), written by Loewenberg et al. (2008) and published in *Journal of Teacher Education*. The review of top ten works revealed that each of them was published after 2000 (Figure 3). Moreover, it was found that all top 10 works with the highest number of citations belong to the cluster #teacher education, which shows that the works performed in mathematics education area mainly focused on this title.

The analysis of the works according to citation bursts showed that 79 works had citation bursts. The work with the highest citation bursts value is *Content knowledge for teaching: What makes it special?*" (49.50), written by Loewenberg et al. (2008) and published in *Journal of Teacher Education*. This work was frequently referred by the studies performed between 2011-2016 and considering that this work belongs to cluster titled as

#teacher education, it can be said that the works performed between 2011-2016 in mathematics education research area mainly focused on this subject (Table 4). The works performed by *Hattie J (#cluster 1), National Research Council (#cluster 1) and Freeman, S (#cluster 12)* had recent citation burst. Regarding the clusters that these works belong, it can be seen that current publications in mathematics education research area focus on #teacher education and #gendered effect topics.

The most studied topics in mathematics education research area were determined based on the titles of the works cited by the studies included in the data set. As a result of the analysis, a total of 26 titles were found and 8 titles with the highest number of citations are shown in Table 5. The titles mostly studied in the field are elementary mathematics classroom (5661.4, 1.0E-4) and teacher education (2854.99, 1.0E-4). Silhouette values of the clusters indicate a homogenous structure. According to Simovici (2007), silhouette value being higher than 0.7 indicates a strong and homogenous clustering. Regarding average citation year of cluster titles, it can be said that elementary mathematics classroom (1989) and teacher education (2009)] are the titles currently studied in the field.

Word analysis

A network analysis was performed for identifying frequently used words in the works published in the field of mathematics education based on the abstracts and keywords of the publications, and thereupon a network
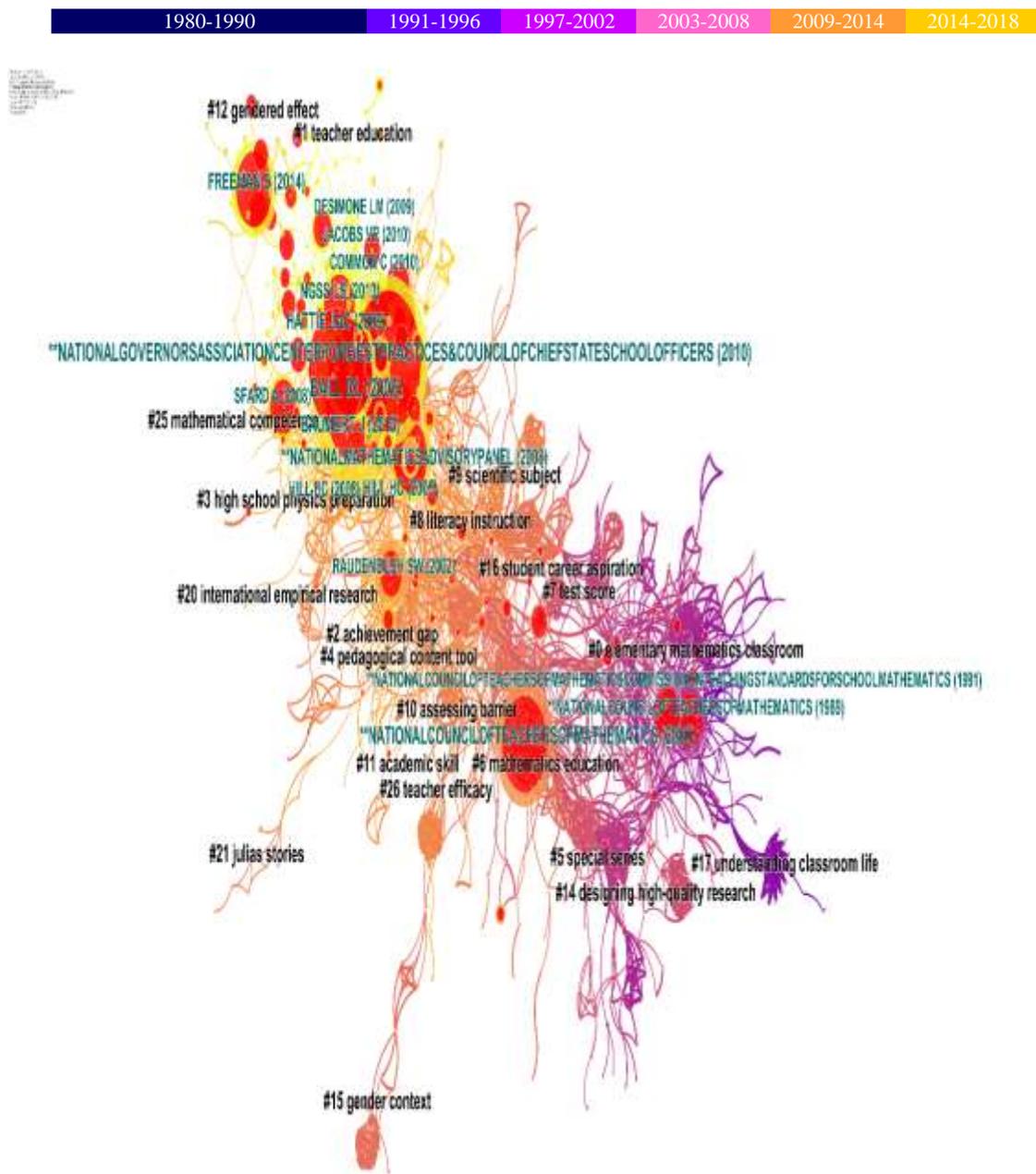
Figure 3. Publication's Common Citation Network.

consisting of 300 nodes (word) and 1,855 connections was obtained. The network density was measured as 0.04, Q modularity value is 0.34 and mean silhouette value is 0.26. The network was divided into 18 separate clusters (Figure 4).

Top 20 words with the highest frequencies, obtained as a result of the analysis, are displayed in Table 6. Accordingly, the concepts that were mostly used in the

works performed in the field were identified as mathematics (n=1841), education (n=1732), student (n=919) and achievement (n=893).

Regarding centrality degrees of the concepts, it can be seen that mathematics (0.15), instruction (0.12), model (0.12) and reform (0.12) have the highest centrality. In this regard, it can be said that these concepts have a key role in the studies performed in the field and they are the

Table 4. Citation Burst Values of Citation Sources.

First Author and References	Strength	Begin	End	1980-2018
Loewenberg Ball (2008) Content knowledge for teaching: What makes it special?	49.50	2011	2016	
National Council of Teachers of Mathematics (2000) Principles and standards for school mathematics	49.36	2001	2008	
Common Core State Standards Initiative (2010) Common Core State Standards for Mathematics (CCSSM).	49.36	2001	2008	
National Council of Teachers of Mathematics (1989) Curriculum and evaluation standards for school mathematics.	37.82	1989	1997	
Hattie J. (2008) Visible learning: A synthesis of over 800 meta-analyses relating to achievement	35.18	2013	2018	
Freeman, S (2014) Active learning increases student performance in science, engineering, and mathematics	34.66	2015	2018	
National Research Council (2013) Next generation science standards: For states, by states.	32.87	2016	2018	
National Council of Teachers (1991) Professional standards for teaching mathematics.	30.46	1992	1999	
Raudenbush, S. W. (2002) Hierarchical linear models: Applications and data analysis methods	27.07	2007	2010	
Hill, H. C (2005) Effects of teachers' mathematical knowledge for teaching on student achievement	25.93	2007	2013	

Table 5. Most studied titles in math/mathematics education research area.

Cluster	Size	Silhouette	Label (TFIDF)	Label (LLR)	Mean (cited year)
0	150	0.87	mathematics	elementary mathematics classroom (5661.4, 1.0E-4)	1989
1	123	0.77	mathematics	teacher education (2854.99, 1.0E-4)	2009
2	82	0.79	mathematics	achievement gap (4706.37, 1.0E-4)	2003
3	80	0.82	science	high school physics preparation (2141.43, 1.0E-4)	2006
4	78	0.81	mathematics	pedagogical content tool (3391.47, 1.0E-4)	2005
5	75	0.96	learning disabilities	special series (4157.96, 1.0E-4)	1993
6	71	0.82	students	mathematics education (1162.51, 1.0E-4)	1997
7	68	0.97	effects	test score (2696.79, 1.0E-4)	1994

keywords of the field.

DISCUSSION

In this study, bibliometric analysis of the academic works concerning mathematics education, published in Web of Science database was performed using Citespace II software; outstanding authors, journals, countries and subject fields were determined; and they are visualized graphically and statistically. The study includes 9,841 works published from 1980-2018 in mathematics education area. Regarding the distribution of the publications according to time periods, it can be said that the number of publications has increased in each period. It can be seen that the highest number of publications was realized from 2015-2018 (46.1%). The network analysis performed to determine the countries of the authors that have made the biggest contributions to mathematics education area in terms of scientific work resulted with a network consisting of 78 nodes (countries) and 393 connections (relationship between countries). The network was divided into 14 clusters. The review of the countries according to the number of publications that they have performed in mathematics education area revealed that most productive countries are USA, England and Turkey. While determining country productivity, if a publication contained two or more

Figure 4. Word analysis.

authors from the same country, the country was counted for once. Regarding the centrality of the countries, it can be seen that the most central countries in the network are England, USA and Spain. It can be said that these countries play an important role in the establishment of scientific communication in mathematics education area and they serve as a bridge. Regarding the ranking of the countries according to the number of citations taken from the scientific studies that they have performed, it can be said that the authors from US, Turkey and Malaysia made the biggest citation bursts, respectively. From this result, it can be concluded that authors from USA have guided the works performed in the field and have made significant contributions to the development of the field. Another result is that authors from Chili are frequently referred by the recent works performed in the field. Based on the titles of the works cited by the studies included in the data set, the subjects mostly studied in the field were found to be elementary mathematics classroom, teacher education and achievement gap. The words that are mostly used in mathematics education research area were found to be mathematics, education, student and achievement. The ranking of the concepts according to their centrality degree revealed that mathematics, instruction, model and reform have the highest centrality values. A network analysis was performed for identifying frequently used words in the works published in the field of mathematics education based on the abstracts and keywords of the publications and according to the outcomes of the analysis mathematics, education, student and achievement were identified as most frequently used words.

Jiménez-Fanjul et al. (2013) performed bibliometric analysis of four journals, which mainly focused on mathematics education, scanned in SSCI between 1986-2011. The authors analyzed Journal for Research in Mathematics Education (JRME), Bolema-Mathematics Education Bulletin-Boletim de Educacao Matematica (BOLEMA), Educational Studies in Mathematics (ESM) and Revista Latinoamericana de Investigación en Matemática Educativa-Relime (RELIME) journals in four main dimensions, namely co-authorship patterns, diachronic production, publication language and universities' productivity of journals. They also analyzed the journals according to various sub-variables, including type of the work, year of the work, language of the work, number of works per university, total number of citations, collaborations, number of authors per article, number of articles per country. As a result of this analysis they found that the number of works starting with 56 in 1986 went to 276 in 2011. These works were respectively article (63.4%), book review (19.5%) and editorial material (8.7%); mostly used languages of publications were English (76.3%), Portuguese (18.6) and Spanish (3.9%). The most productive universities were respectively Michigan State University (1.5%), University of Georgia (1.3%) and Purdue University (1.3%). A total of 7805 citations were made to the works, average number of citation per work was 9.06; regarding the number of authors, the works with single author was 38.6%, whereas works with two authors were 35.9% and with three authors, 14.2%. Regarding the country

Table 6. Most used words in math/mathematics education research area.

Key words	Count	Keywords	Centrality
mathematics	1841	Mathematics	0.15
education	1732	Instruction	0.12
student	919	Model	0.12
achievement	893	Reform	0.12
mathematics education	714	Knowledge	0.10
science	657	Children	0.09
knowledge	619	Achievement	0.08
performance	566	School	0.08
school	546	Classroom	0.08
classroom	505	Student achievement	0.08
instruction	483	Education	0.07
teacher	429	Student	0.07
children	337	High school	0.07
professional development	308	Teacher	0.06
motivation	307	Curriculum	0.06
curriculum	295	Outcome	0.06
belief	295	Science	0.05
teacher education	290	Performance	0.05
technology	281	Motivation	0.05
Model	263	Attitude	0.05

contributions, they were ranked as US (32.4%), Brazil (15.8%) and Canada (5.9%).

Yalçın and Yayla (2016) addressed the researches made in Technological Pedagogical Content Knowledge (TPACK) area to reveal scientific communication of the researchers, determine the publications and authors that were active in the field and present comprehensive results in terms of author and publication. The study was conducted with a total of 543 publications addressing TPACK, in the form of book, article and review, obtained from Web of Science (WoS) and Scopus databases. Scientific communication pattern of TPACK field was addressed according to authors and works by using bibliometric method; and the authors and researches that came to the forefront were presented by visualizing via scientific mapping. By this means, comprehensive results were revealed using the publications and their authors.

Özsoy et al. (2017) categorized and analyzed 103 postgraduate and doctoral theses concerning mathematics education in classroom teaching, published in Turkey from 2005-2016. The categories were set as impact, book, teacher, student and curriculum according to the work areas of the theses. Postgraduate theses published in the defined years were analyzed according to the universities, academic titles of the advisors, years, research patterns and samples/workgroups. According to the results of the research, it was found that research patterns that have been mostly used in the theses were

scanning model, experimental design and qualitative design. Most preferred compositions in the researches were respectively 1-8th grade students, teachers and teacher candidates. It was found that works were concentrated around numbers and geometry.

Assefa and Rorissa (2013) analyzed the article's titles, keywords and abstracts concerning STEM education area in Web of Science and ERIC databases. The researchers used common word analysis method, figures and maps to look for clues about how STEM education will be shaped in the future, whether it will provide information that will illuminate the works of the educators who plan curriculums. For this purpose, they have scanned books, papers, articles and theses that included STEM education words in Web of Science and ERIC databases, published from 1901 to 2010. The researchers addressed various questions including, what are the main knowledge areas in STEM education and the relationships among them; how to use these results in developing curriculums; how to use these results in resource management and professional improvement activities.

The data set used in this study was formed based on the works concerning mathematics education, published in WoS database between 1980-2018. In this regard, this study can be described as the study having the most extensive data set compared to the works in which similar methods had been used; it aims to reveal the general

status of the field. This study is a pioneer for future works that will use similar methods. The collaboration pattern reached as a result of the study and collaboration structure belonging to outstanding works and authors should be considered as a guide that will form a starting point for future researches.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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