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Research Article

Mapping and performance evaluation of mathematics education research in Turkey: A bibliometric analysis from 2005 to 2021

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Different types of in-depth literature reviews were conducted to identify, evaluate or summarize the findings, common themes, trends, gaps, and used methods in mathematics education research. In recent decades, technological advances have enabled us to evaluate mathematics education literature in a more reliable, powerful, and objective manner. This study aims to present a complete description of Turkey-addressed mathematics education research using bibliometric methods. In other words, the current study aims to identify the most influential and/or productive authors, institutions, and publications in the field of mathematics education in Turkey. This study also aims to visualize and uncover the dynamic of the conceptual and intellectual structure of the field. For this purpose, citation analysis, co-occurrence analysis, co-citation analysis, and science mapping were performed using 416 highly-qualified and SSCI-indexed articles obtained from the WoS database. The results of citation analysis indicate the most influential authors are A. Baki, B. Guven, and D. Akyuz, respectively while the most productive ones are M. Isıksal-Bostan, A. Kursat Erbas, and O. Birgin. The most effective and leading institutions in the field are METU, Karadeniz Technical, and Hacettepe Universities. Additionally, co-occurrence analysis indicates mathematical achievement, mathematical modelling, and attitude are the most commonly used author keywords. Co-citation mapping visualizes the knowledge base of the mathematics education research and uncover which subjects the scholars in the field benefited from the research studies of seminal authors. Based on the findings, the current study makes suggestions for the research topics that could be influential and needed further research in the field.

Keywords: Bibliometric analysis; Science mapping; Mathematics education; Co-citation analysis; VOSviewer; SSCI

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1. Introduction

In the late 1960s, mathematics education research emerged as a scientific discipline (Aydın, 1990; Jankvist et al., 2021). A broad focus of mathematics education research is how students learn mathematics and do mathematics, as well as how they affect mathematics instruction (Dörfler, 2003). According to Schoenfeld (2000), the main purpose of mathematics education research is to improve mathematics instruction through the insights gained by trying to understand the nature

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of mathematical learning, teaching, and thinking. In other words, the knowledge grasped as a result of mathematics research affects mathematical teaching methods, mathematics instruction, mathematics teacher education and mathematics education policies. The systematic evaluation of the studies on mathematics education is useful for examining the current situation of mathematics education, determining current trends and identifying future trends (Ulutaş & Ubuz, 2008).

Technology developments have enabled more powerful methods to find and evaluate relevant literature (e.g., bibliometric analyses) over the last few decades (Drijvers et al., 2020). Various parameters are used to determine the quality or value of scientific studies and the productivity of scientists. Research evaluation studies examining these parameters are in the field of bibliometric analysis methods (Al, 2008). Bibliometric analysis uses statistical methods for analyzing books, articles, and other publications. Bibliometric analysis employs statistical analysis to describe, evaluate and monitor published literature with respect to bibliometric data, including citation information regarding authors, publications, institutions, journals, and countries (Zupic & Cater, 2015). In addition to this, the topics studied in a specific research field or country, the authors focusing on these topics, the cooperation among the authors, and the topics of more or less interest could be determined by bibliometric analysis (Zan, 2012). Unlike traditional literature reviews that could include interpretation bias (e.g., systematic literature review, meta- synthesis) or publication bias (e.g., meta-analysis), bibliometric analysis provides more objective evaluation of the literature. Bibliometric analysis provides significant contributions in terms of directing researchers to the most effective studies even before they start reading, enabling them to quickly find research gaps in the field, inspiring new ideas for research, revealing research trends and mapping the research area to see the conceptual, social or cognitive structure (Donthu et al., 2021; Zupic & Cater, 2015). Bibliometric analysis conducted on mathematics education will enable to determine the research trends, the areas where studies are concentrated, new trends, gaps, topics, concepts, or areas that need more study in the field. This will make significant contributions to mathematics education researchers, program developers, graduate students, and policy makers. Nevertheless, there is little research on bibliometrics analysis regarding mathematics education. Özkaya (2018) examined the studies in mathematics education between the years 1980-2018 with the bibliometric analysis method to determine the social structure and cognitive structure of mathematics education research. In a similar way, Güner and Gökçe (2021) conducted a study aiming to reveal trends and identify evolution in mathematics education research between 1980-2019. Even though there are aforementioned bibliometric research studies on mathematics education, none of them have not focused on revealing the intellectual, conceptual and social structure of the mathematics education research in Turkey. Therefore, the aim of the current study is to determine the most influential authors, universities, keywords, and publications and to uncover the dynamics of conceptual structure and intellectual structure of the mathematics education research field in Turkey.

2. Types of Bibliometrics Analysis

Although there are many different types of bibliometric analysis, the most widely used bibliometric analysis methods in scientific research are citation analysis, co-citation analysis, co-occurrence (co-word or keyword) analysis, bibliographic coupling and co-author analysis (Van Eck & Waltman, 2014; Zupic & Cater, 2015). Of these analysis methods, *citation analysis* is the most widely used, which is a powerful method that aims to determine influential publications, authors, journals and institutions in a specific scientific discipline (Gülmez et al., 2020; Hallinger & Kovacevic, 2020; Hou et al., 2018; Karadağ et al., 2017; Linan & Fayolle, 2015; Zupic & Cater, 2015). Citation analysis is considered a measure of impact of the relevant research unit (e.g., author, institution, and journal) in a scientific field or its scientific quality. In addition, it is assumed that a research unit, which receive more citations, are more significant than the others (Zupic & Cater, 2015). The basic idea is that getting more citations in a scientific field indicates higher importance, quality, and remarkable (Donthu et al., 2021; Gundolf & Filser, 2013).

Waltman (2017) classified the basic indicators that can be utilized to measure citation-based impact into two groups: size-dependent indicators and size-independent indicators. Size independent indicators are *the total number of citations*, *the number of highly cited publications*, and *h-index*. On the other hand, size-depended indicators are *the average number of citations per publications* and *the proportion of highly cited publications*. While the total number of citations represents the number of all citations received by the publications of a research unit, the average number of citations is calculated by dividing the total number of citations by the total number of publications. When the minimum citation criteria for a publication is determined, the number of publications of a research unit that meet this threshold is defined as the number of highly cited publications. The ratio obtained by dividing the number of highly cited publications by the number of all publications for a research unit is identified as the proportion of highly cited publications. The h-*index* indicates that each of h publications of any research unit receives at least h citations. Besides the impact of a research unit, indicators that can reveal its productivity can be considered as the total number of publications (Donthu et al., 2021), the number of highly cited publications, or the proportion of highly cited publications. In addition, there are normalized citation impact indicators that allow us to accurately compare the impact of publications published in different fields, documents published in different years, or documents of different types (e.g., article, review, and letter) (Waltman, 2017). The current study employs *normalized citation* and *average normalized citation* indicators. Dividing the total citations of a document by the average number of citations of all documents published in the same year is the normalization citation score. The average normalized citation score is calculated by dividing the total normalized citation score of a research unit by the total number of documents of the research unit (Van Eck & Waltman, 2021).

Co-occurrence (co-word or keyword) *analysis* reveals the concepts that frequently appears in titles, abstracts or keywords of the publications in a scientific field and the cognitive structure of the field, which is based on thematic clusters formed through the relationships between the concepts. The co-occurrence analysis visualizes the cognitive structure of the field as a conceptual network. The co-occurrence analysis provides insight into the most popular topics (ideas or understanding), patterns, trends and the topics that might gain more attention in the future (Ellegaard & Wallin 2015; Ding et al., 2011; Donthu et al., 2021; Wang & Chai, 2018; Zupic & Cater, 2015).

Co-citation analysis establishes a connection between two research units if they are both included in the bibliography of the other research unit. In the co-citation analysis, if two or more research units are frequently cited together, they have strong co-citation relationships (Small, 1973; Van Eck & Waltman, 2014). The research units with the strong co-citation relationships come together under similar thematic clusters, and therefore, the co-citation analysis visualizes the intellectual structure of a scientific field (He & Hui, 2002; Jeong et al., 2014; White & Griffith, 1981). One of the important benefits of co-citation analysis is that it uncovers the seminal works and knowledge base in a scientific discipline (Donthu et al., 2021).

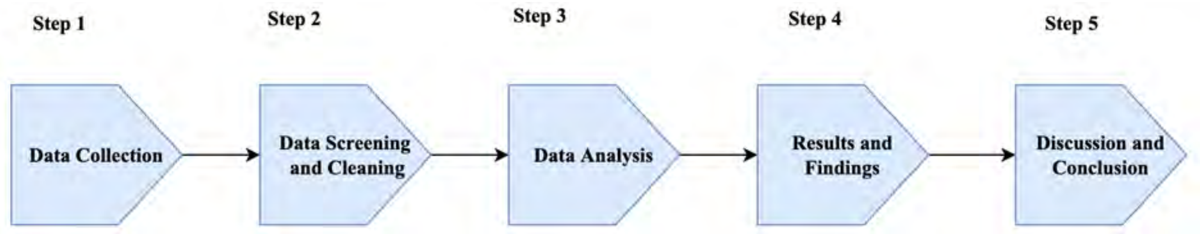
Along with the co-citation analysis, *co-author analysis* is the most utilized method to reveal the social collaboration of a scientific field (Rousseau et al., 2018). This analysis method tries to uncover the social structure rather than the intellectual structure of authors. Suppose two authors publish a document together. Then a co-author relationship is established between them, and the relationship is considered a measure of collaboration (Lu & Wolfram, 2012).

When two publications commonly share at least one publication in their bibliographies, it means there is a *bibliographic coupling* link between them (Ferreira, 2018; Glanzel & Czerwon, 1996; Kessler, 1963; Lu & Wolfram, 2012). The link is a measure of similarity between the contents of the publications. As the number of common publications, they share in their bibliographies increases, the link strengthens and the similarity increases (Lu & Wolfram, 2012). The point to be noted here is that unlike co-citation analysis, the common references between the two publications do not change over time and remain the same (Jarneving, 2005; Lu & Wolfram, 2012). In contrast to co-citation analysis, it is the visualization of co-citing publications in thematic clusters. Thus, while bibliographic coupling substantially shows current studies at visualization, old and seminal studies appear in co-citation analysis. In other words, bibliographic coupling depicts the current state of the intellectual structure in a scientific field (Boyack & Klavans, 2012).

3. Method

Bibliometric analysis method is used in this study to examine the literature related to mathematics education research. Bibliometric method is an application of quantitative data analysis to explore, evaluate and examine a large volume of scientific data (Donthu et al., 2021; Ellegaard & Wallin, 2015; Lee et al., 2020; Wallin, 2005; Zupic & Cater, 2015). It is also referred to science mapping and enables to determine of trends, gaps, social networks, intellectual structure and cognitive structure in a given research field (Börner et al., 2003; Donthu et al., 2021; Van Eck & Waltman, 2014; Zupic & Cater, 2015). Moreover, it also contributes to assessing which are the most influential articles, themes, authors, universities or journals in a given research field. The current research study employs citation analysis, co-occurrences analysis and co-citation analysis to evaluate Turkey-addressed articles published in the mathematics education field. We aim to find the most influential articles, authors, and universities related to mathematics education research in Turkey with citation analysis. Co-occurrence analysis provides which themes have more impact on the research, while co-citation analysis presents the knowledge base of the research and its intellectual structure. The overall procedures in the current study are shown in Figure 1.

Figure 1
The Workflow of the Current Research Study



3.1. Data Collection

The bibliometric data were retrieved from the Web of Science (WoS) bibliometric database on December 25, 2021. WoS bibliometric database was chosen in this study because it is the most widely used and accepted database, including all records of high-quality research publications as well as it is still considered as one of the main bibliographic sources of information (Birkle et al., 2020; Gürlen et al., 2019; Lee et al., 2020; Zhang et al., 2015). Zupic and Cater (2015) suggested two approaches to obtain appropriate bibliometric data comprising the publications in the focus of research: 1) searching for selected keywords 2) searching articles published in a single journal or a small number of journals. In the current study, we preferred the first approach since our purpose is to reach as many articles as possible related to mathematics education research. First of all, we identified some important criteria for deciding which articles to be involved in this study. As can be seen in Table 1, in the line with the purpose of this study to reach publications originating from Turkey, the location for the publications was set as Turkey. In addition, the original peer-reviewed publications in the journals indexed social science citation index (SSCI) and the publications written only in English or both English and Turkish were included in the study. The document type for the publications was limited to only articles using the filtering options. In addition to the above restrictions, the articles published until December 25, 2021 were included in this study. Before the initial search, we created a list of all the potential search terms relevant to the current research. We started the search using the "math* education" term and continued to respectively add each of new research terms to the list until we reached the maximum number of articles. Thus, we obtained the final search terms shown in Table 1, and they were yielded a total of 548 articles in the WoS database.

According to Zupic and Cater (2015), the results of a database search with an array of selected keywords may contain irrelevant publications that are not the scopes of an intended research. A situation like this may affect the results of bibliometric analysis by reducing the validity of the research. Thus, to determine the uninterested publications, we independently reviewed the abstracts of all 548 articles. After the examination and discussion processes, we decided to incorporate only 416 articles instead of 548 articles in the final bibliometric data. In other words, the articles related to science education or those using mathematics teachers within only their samples without focusing on mathematics education research were excluded in the current research. Therefore, finally, the bibliometric data consisted of 416 articles were downloaded from the WoS database.

Table 1
Criteria for the Selection of the Publications

Criteria	*Value*
Data Source	Web of Science
Search Terms	"math* education" or "math* teaching" or "teaching math*" or "algebra teaching" or "teaching algebra" or "math* learning" or "learning math*"or "math* knowledge" or "math* thinking" or "math* understanding" or "math* reasoning" or "math* problem solving" or "problem-based learning"
Publication Period	until December 25, 2021
Location	Turkey
Document Type	Article
Citation Index	SSCI
Language	English and Bilingual (both English and Turkish)
Number of Articles	416 / (548)

3.2. Data Screening Cleaning

Data cleaning is a curial step to getting more precise and reliable results before proceeding with data analysis since bibliometric data may include duplicate, wrong and missing entries (Cobo et al., 2011a; Donthu et al., 2021; Van Eck & Waltman, 2014; Zupic & Cater, 2015). Due to bibliometric data are editable, we examined it to identify and minimize the possible errors and duplications prior to each analysis. These investigations in the current study showed there were four types of errors: 1) misspelling of an author's names (e.g., Ebru Guveli was appeared as "Gueveli, E."), 2) duplications of an author's names in different formats (e. g., Mine Isiksal Bostan was seen as "Isıksal-Bostan, M., "Isıksal Bostan, M.", "Isiksal, M" or "Bostan, M. I."), 3) duplications of an author's affiliation in different formats (e.g., Middle East Technical University was seen as " middle east tech univ", "middle e tech univ", or "orta doğu tekn univ"), and 4) missing publication time of an article. With these determinations and the use of thesaurus files, we fixed duplicate, incorrect and missing entries in the bibliometric data.

3.3. Data Analysis

All data consisting of 416 publications were downloaded from WoS and a series of bibliometric (scientometric) analyses was carried out with the use of VOSviewer software with version 1.6.17. VOSviewer is a freely accessible and distance-based visualization tool to create bibliometric maps showing intended networks within large data (Van Eck & Waltman, 2010; Van Eck & Waltman, 2011; Van Eck & Waltman, 2014; Van Eck & Waltman, 2021). VOSviewer software constructs a map of the network encapsulating only items of interest (e.g., publications, authors or keywords, etc.) and links (e.g., co-citation from same publications, co-authorships or co-occurrences, etc.) between them. Bibliometric analysis is grouped into two categories, performance analysis and science mapping (Cobo et al., 2011b; Donthu et al., 2021; Gutierrez-Salcedo et al., 2018; Noyons et al., 1999; Zupic & Cater, 2015). Performance analysis is conducted to investigate the contributions of research elements in a given research field, such as the total number of publications or citations received by an author and the average number of citations of an article by year (Cobo et al., 2011b; Donthu et al., 2021). Here, the total number of citations or average normalized citations is an indicator of how an author or a publication is influential in the research field while the number of publications represents productivity. Science (bibliometric) mapping provides a visual representation of the intellectual structure and its evolution in the research field. In addition, it gives insight into how research elements interact and connect with each other and the strength of relationships between them (Donthu et al., 2021; Noyons et al., 1999; Small, 1999; Zupic & Cater 2015). Science mapping consists of 5 different analysis techniques: co-authorship, co-citation, co-occurrence, citation, and bibliographic coupling.

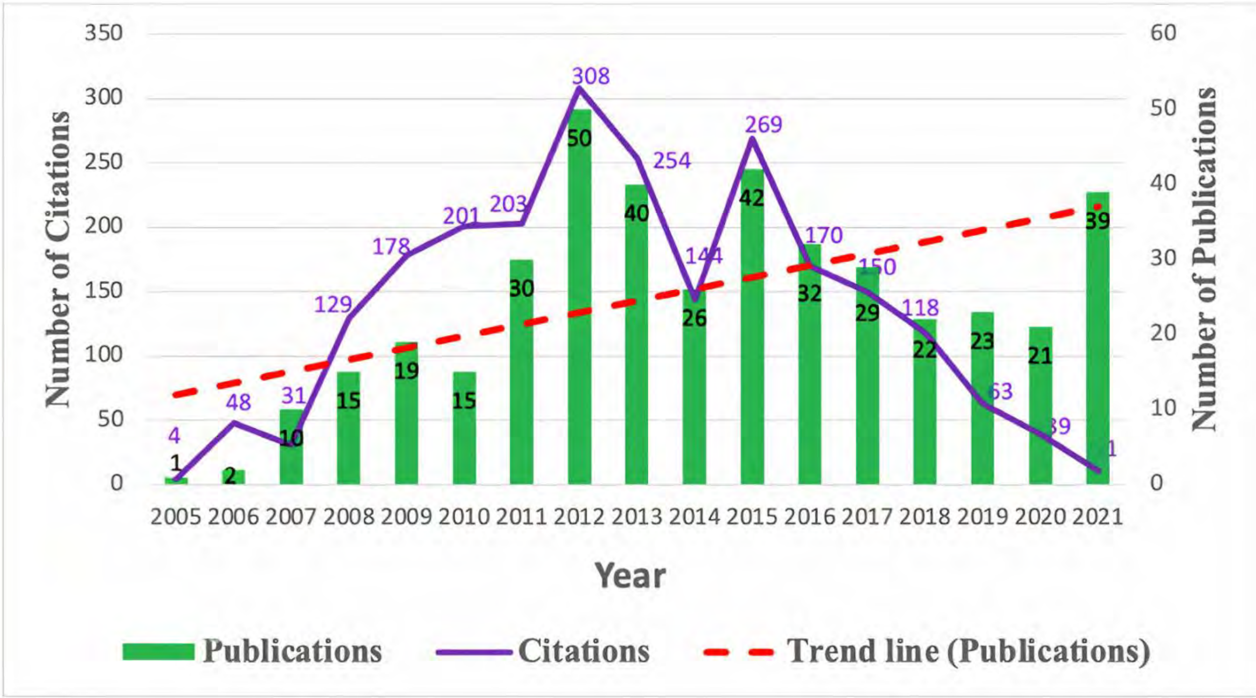
In the current study, we employed both performance analysis and science mapping to examine and interpret the cognitive and intellectual structure of mathematics education research addressed to Turkey. Citation analysis was conducted to determine the most prominent, effective and valued publications pertaining to mathematics education. Moreover, we carried out citation analysis to reveal most influential authors and universities. On the other hand, co-citation analysis was performed to visualize the network of authors who have seminal and leading publications for mathematics education research. Finally, we conducted co-occurrence analysis to reveal notable and promising keywords or key-terms that would be the center of the mathematics education research in the future.

4. Results and Findings

A descriptive statistical analysis was conducted to find out the trends of the number of publications and citations by years. Figure 2 shows the overall trends in both the number of publications and the citations related to mathematics education over the years. While the articles

Figure 2

The Total Number of Publications and Citations by Years



on mathematics education research were published between 2005 and 2021, more than half (approximately 54%) of all research articles were published between 2011 and 2016. The highest increase in the number of articles compared to the previous year occurred in 2012, while the fastest decrease in those compared to the previous year was 2014. Even if there were some fluctuations in the number of publications over the years, it frequently displayed an upward trend. Although the number of articles annually decreased from 2016 to 2021, it reached 39 in 2021 exceeding average number of articles (25) over the years. Trends in the number of citations (except for 2010) showed parallelism with those of publications until 2018. The number of average citations in 2010 is more than those in the following years. The articles published after 2018 were cited less frequently. This is not surprising since while there were 90 uncited articles in total, more than half (47) of them were published after 2018. This could be explained by the fact that older articles may have received more citations due to the effect of time.

4.1. Citation Analysis with Authors

Citation analysis was conducted to identify the most productive and effective authors in the field of mathematics education research in Turkey. An author's both number of citations and articles were selected as at least one in WoSviewer, and thus, 457 authors out of 571 met this threshold. Among these authors, 172 authors with the highest total link strength and connected with each other were used to create science mapping and performance analysis. Table 2 shows the top 20 authors, sorted by the number of total citations. In addition, the performance values of the authors are presented in Table 2. As seen in Table 2, the three most productive authors in the field are M. Isıksal-Bostan, A. Kursat Erbas, and O. Birgin, respectively. Considering the average year of publications, D. Akyuz, M. Isıksal- Bostan and E. Cakıroglu are recently the most productive authors. The three authors who are the most influential in the field are A. Baki, B. Guven, and D. Akyuz, in turn. Given the normalized citations, evaluating the number of citations in an article with average citations of all articles published in the same year, the findings indicate A. Baki, D. Akyuz, and A. Kursat Erbas would continue to be highly impactful authors in the area of mathematics education research.

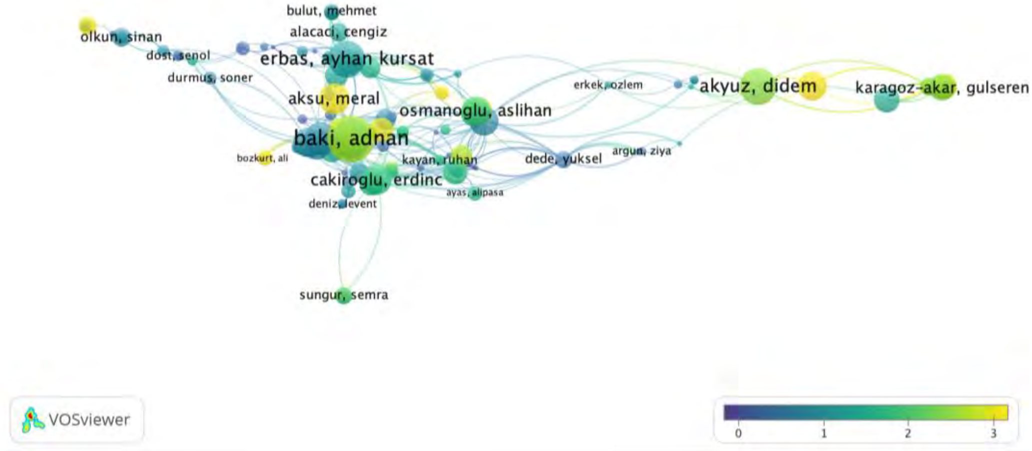
Table 2
The Most Cited 20 Authors

Scholar	*Number of Articles*	*Total Citations*	*Avg. Citations*	*Norm. Citations*	*Avg. Norm Citations*	*Avg. Pub. Year*
Baki, Adnan	9	166	18.44	22.70	2.52	2011
Guven, Bulent	10	111	11.10	16.48	1.65	2012
Akyuz, Didem	8	103	12.88	19.00	2.37	2016
Erbas, Ayhan Kursat	15	103	6.87	16.53	1.10	2013
Birgin, Osman	11	84	7.64	8.96	0.81	2012
Aksu, Meral	3	73	24.33	11.95	3.98	2014
Ozyurt, Hacer	4	73	18.25	11.88	2.97	2013
Gurbuz, Ramazan	9	72	8.00	7.13	0.79	2012
Cakiroglu, Erdinc	9	68	7.56	15.87	1.76	2015
Catlioglu, Hakan	7	65	9.29	5.86	0.84	2011
Ozyurt, Ozcan	4	64	16.00	7.73	1.93	2013
Osmanoglu, Aslihan	3	64	21.33	10.41	3.47	2013
Stephan, Michelle	3	62	20.67	10.06	3.36	2012
Isiksal-Bostan, Mine	19	62	3.26	14.43	0.76	2016
Koc, Yusuf	4	60	15.00	6.77	1.69	2011
Cakiroglu, Unal	4	56	14.00	5.93	1.48	2011
Pilli, Olga	1	54	54.00	8.50	8.50	2013
Karagoz-Akar, Gulseren	2	53	26.50	4.52	2.26	2013
Peker, Deniz	1	52	52.00	5.55	5.55	2009
Zembat, Ismail Ozgur	3	49	16.33	3,90	1.30	2011

Figure 3 indicates the average normalized citations of the authors. In Figure 3, while the size of a node represents the total number of citations an author has received, the color of the node represents the score of average normalized citation. In other words, the colors of nodes indicate the extent to which the authors are influential in the field. Authors represented by yellow color have the most influence in the field while authors with blue colors have less influence.

Figure 3

Overlay Visualization of Authors (Average Norm Citations)



4.2. Citation Analysis with Universities

We also performed citation analysis to find the most contributing and influential universities to the research field of mathematics education in Turkey. The minimum number of articles of a university was set as at least 1. Thus, 154 universities satisfied this threshold. In addition, we utilized the most connected 87 universities from a total of 154 for further analysis and science mapping. As seen in Table 3, Middle East Technical University (METU) is the most productive institution in terms of the total number of articles. Hacettepe and Gazi Universities are the other two most contributing institutions to the field. Considering the highly influential universities in

Table 3

The Most Efficient 20 Universities

Universities	*Number of Articles*	*Total Citations*	*Avg. Citations*	*Norm. Citations*	*Avg. Norm Citations*	*Avg. Pub. Year*
Middle East Tech Univ.	67	481	7.18	88.05	1.31	2015
Karadeniz Tech Univ.	26	308	11.85	40.49	1.56	2012
Hacettepe Univ.	35	125	3.57	21.67	0.62	2013
Anadolu Univ.	15	104	6.93	11.44	0.76	2013
Ataturk Univ.	16	99	6.19	16.92	1.06	2013
Marmara Univ.	20	99	4.95	12.99	0.65	2013
Adiyaman Univ.	14	96	6.86	11.36	0,81	2013
Bogazici Univ.	11	90	8.18	11.29	1.03	2015
Cukurova Univ.	9	85	9,44	13.44	1.49	2012
Gazi Univ.	30	83	2.77	16.23	0.54	2015
Dicle Univ.	12	81	6.75	16.04	1.34	2015
Abant Izzet Baysal Univ.	16	78	4.88	13.55	0.85	2015
Pamukkale Univ.	8	69	8.63	10.94	1.37	2012
Trakya Univ.	5	65	13.00	7.91	1.58	2014
Univ. North Carolina	5	63	12.60	10.55	2.11	2015
Indiana Univ Bloomington	7	61	8.71	11.33	1.62	2018
Eastern Mediterranean Univ.	1	54	54.00	8.50	8.50	2013
Virginia Tech	1	52	52.00	5.55	5.55	2009
Gaziosmanpasa Univ.	3	50	16.67	5.25	1.75	2013
Arizona State Univ.	2	48	24.00	3.58	1.79	2010

mathematics education research in Turkey, METU, Karadeniz Technical, and Hacettepe Universities stand out in terms of both the number of total citations and normalized citations. Given the average publication year, it is seen that recently most active institutions are METU, Bogazici, Gazi, Dicle, and Abant Izzet Baysal Universities. Additionally, some educational institutions not addressed from Turkey were included in Table 3 due to collaborations of authors on the same publications.

Figure 4
Network Visualization of the Universities

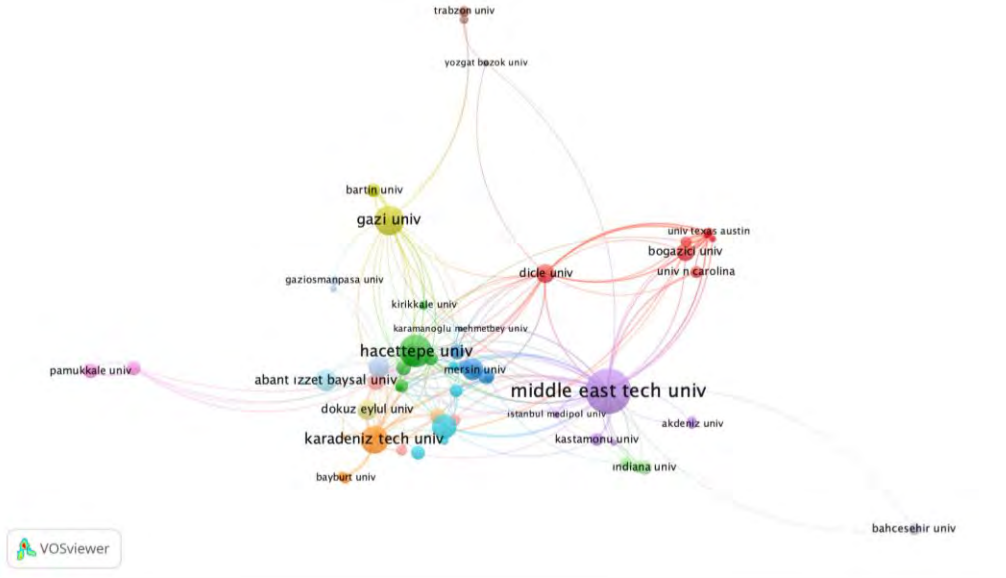
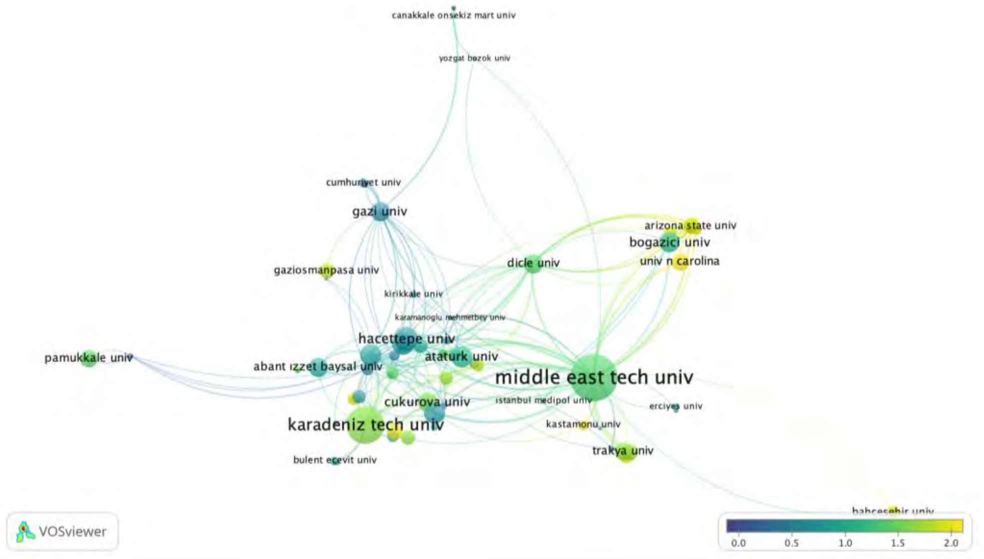


Figure 5
Overlay Visualization of the Universities (Average Norm Citations)



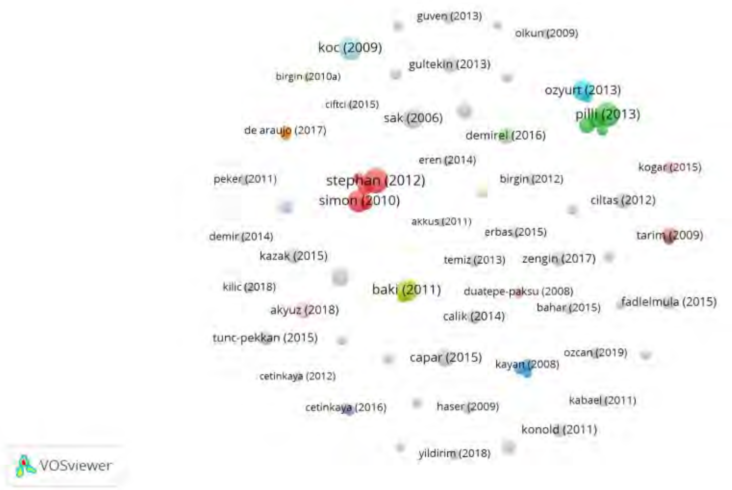
4.3. Citation Analysis with Articles

To determine highly cited and notable articles in mathematics education research, we set the minimum number of citations for an article as at least 10 in VOSviewer. Only 73 articles out of 416 met this threshold. Visualization of these articles is displayed in Figure 6. Table 4 shows the most influential 15 articles, sorted by normalized citations. As shown in Table 4, Stephan and Akyuz by their research study have the highest impact on mathematics education research. When these articles were examined, it was seen that 7 articles used quantitative methods, 7 of them used qualitative methods, and 1 article used mixed methods. The highlighted topics for the quantitative studies consist of technology-based mathematics education, the effects of using technology-supported materials, meta-analysis research and mathematical problem-solving. The qualitative studies focused on teacher education and professional development, instructional theories and students' learning. The mixed method study concentrates on the effects of technology-based materials on students' understanding. In addition, another finding that should draw attention is that 4 of these articles are literature review studies.

Table 4
The Most Influential 15 Articles

Authors	*Title*	*Total Citations*	*Norm. Citations*
Stephan and Akyuz (2012).	A proposed instructional theory for integer addition and subtraction	58	9.42
Pilli and Aksu (2013).	The effects of computer-assisted instruction on the achievement, attitudes and retention of fourth grade mathematics students in North Cyprus	54	7.4
Baki et al. (2011).	A comparative study of the effects of using dynamic geometry software and physical manipulatives on the spatial visualization skills of pre-service mathematics teachers	43	6.35
Koc et al. (2009).	Supporting teacher professional development through online video case study discussions: An assemblage of preservice and inservice teachers and the case teacher	52	5.55
Ozyurt et al. (2013).	Design and development of an innovative individualized adaptive and intelligent e-learning system for teaching–learning of probability unit: Details of UZWEBMAT	40	5.48
Capar and Tarim (2015).	Efficacy of the Cooperative Learning Method on Mathematics Achievement and Attitude: A Meta-Analysis Research	35	5.46
Akyuz (2018).	Measuring technological pedagogical content knowledge (TPACK) through performance assessment	27	5.03
Ozcan and Eren-Gumus (2019).	A modeling study to explain mathematical problem-solving performance through metacognition, self-efficacy, motivation, and anxiety	13	4.75
Demirel and Dagyar (2016).	Effects of problem-based learning on attitude: A meta-analysis study	24	4.52
Ellis et al. (2016).	An exponential growth learning trajectory: Students' emerging understanding of exponential growth through covariation	23	4.33
Ciltas et al. (2012).	Mathematics Education Research in Turkey: A Content Analysis Study.	26	4.22
Demirel and Dagyar (2016).	Effects of problem-based learning on attitude: A meta-analysis study.	21	3.79
Simon et al. (2010).	A developing approach to studying students' learning through their mathematical activity	48	3.58
Kazak et al. (2015).	Combining scaffolding for content and scaffolding for dialogue to support conceptual breakthroughs in understanding probability	22	3.43
Baki and Guveli (2008).	Evaluation of a web-based mathematics teaching material on the subject of functions	29	3.37

Figure 6
Network Visualization of the Most Influential Articles



4.4. Co-occurrence Analysis

We performed co-occurrence analysis to find out the most focused and accentuated contents, topics, or keywords in the mathematics education research field. While doing this, the minimum number of occurrences of a keyword was selected as 5 and thus 57 keywords out of 851 satisfied this criterion. While considering average normalized citations, the most occurred 25 keywords are shown in Table 5. Although the most frequently occurred keywords are mathematics education

Table 5
The Most Used Keywords, Sorted by Average Normalized Citations

Keywords	*Occurrences*	*Avg. Cit.*	*Avg. Norm. Cit.*	*Avg. Pub. Year*
Meta-analysis	6	12.83	2.18	2016
Mathematical problem solving	6	8.67	1.92	2016
Self-efficacy	10	8.80	1.91	2014
Cooperative learning	7	12.71	1.86	2014
GeoGebra	9	7.22	1.79	2017
Anxiety in mathematics	5	7.60	1.73	2017
Structural equation modeling	9	6.56	1.71	2018
TPACK	7	7.71	1.71	2017
Content analysis	6	10.00	1.62	2014
Technology-based mathematics ed.	12	10.25	1.58	2013
Spatial ability	5	8.60	1.51	2014
Geometry teaching	9	3.11	1.49	2016
Functions and functional thinking	5	11.60	1.48	2011
Proportional reasoning	5	6.20	1.40	2018
Problem based learning	5	7.40	1.39	2015
Attitude	20	8.25	1.31	2014
Mathematical achievement	32	8.38	1.28	2014
Middle school students	13	7.00	1.17	2015
Dynamic geometry environment	9	5.22	1.14	2016
Mathematical modeling	20	6.80	1.10	2014
Mathematics teachers	6	4.83	1.10	2016
Curriculum	12	6.50	1.07	2015
Noticing	12	2.92	1.07	2018
Metacognition	11	4.45	1.06	2016
Gender	5	10.80	1.03	2012

and prospective teachers (see Figure 7), these terms are excluded in Table 5 due to the fact that their average normalization citations are less than the others. According to Table 5, it can be said that more research has been done on mathematical achievement, attitude, mathematical modeling, middle school students and technology-based education. On the other hand, more remarkable and effective studies in the field have concentrated on the keywords related to meta-analysis, mathematical problem solving, self-efficacy, cooperative learning, and GeoGebra. Given the average publication year, it is seen that the highly influential studies in the last period have focused on structural equation modeling, proportional reasoning, noticing, GeoGebra, anxiety in mathematics and TPACK (see Figure 8).

Figure 7 visualizes the network of the keywords which frequently occurred in mathematics education research. The nodes in the network represent each of 57 keywords, and the size of a node indicates the number of occurrences of a keyword across different studies. While the lines among nodes, if there, point out the two-connected keywords co-occurred in a research study, the thickness of the line represents the number of co-occurrences. Colors show which clusters the nodes belong to. As seen in Figure 7, there are eight clusters for mathematics education research in Turkey. When examining the first three clusters with the highest number of items, the red cluster consists of the keywords of teacher training, mathematical knowledge, mathematical knowledge for teaching (MKT), TPACK, validity, reliability, fractions, gender, mathematics, values in mathematics and PISA. The green cluster includes the keywords of mathematical modeling, mathematical thinking, algebra, and algebraic thinking, generalizations, misconceptions, middle school students, elementary mathematics education, and content analysis. The studies in the blue cluster seem to be focused on mathematical problem solving, prospective teachers, pedagogical content knowledge (PCK), anxiety, structural equation modeling, spatial ability, integral, metacognition, functions, teacher education, and scale development.

Figure 7
Network Visualization of the Most Co-occurred Keywords

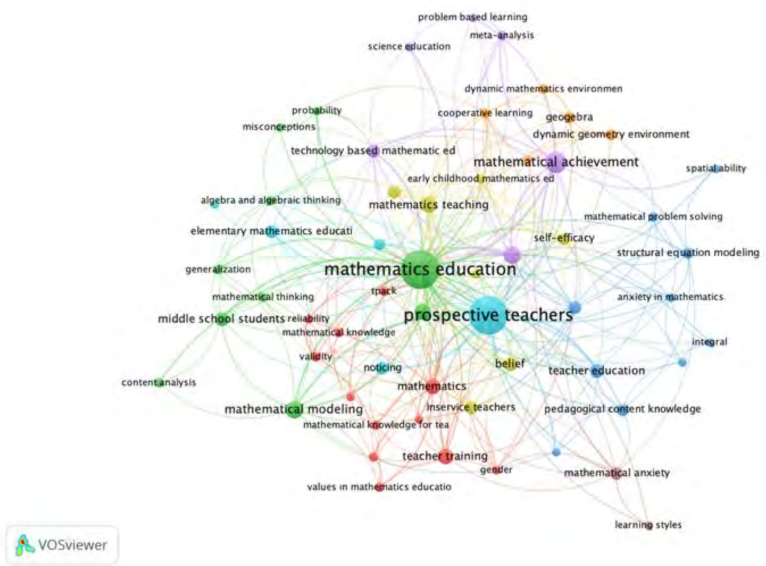
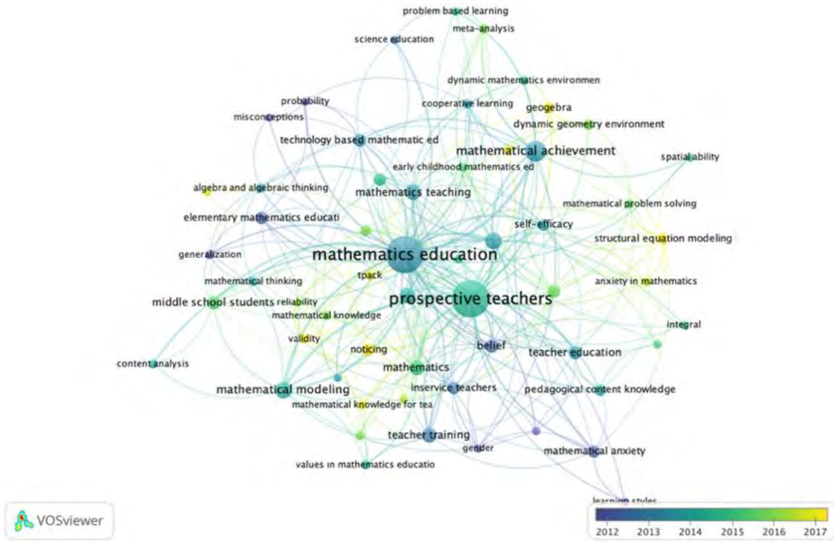


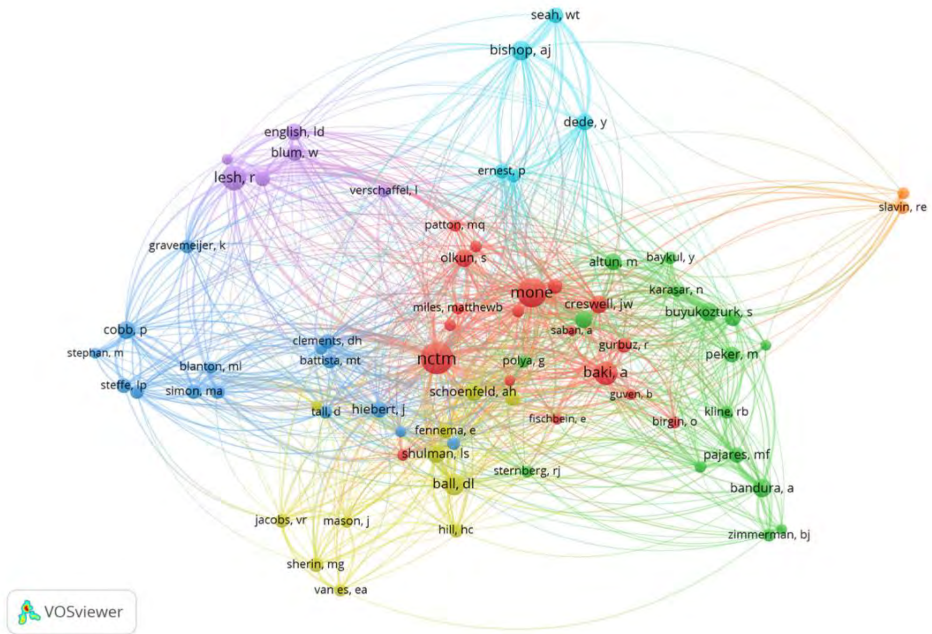
Figure 8
Overlay Visualization of the Most Co-occurred Keywords (Average Publication Year)



4.5. Co-Citation Analysis

An author co-citation analysis was performed to identify and visualize the intellectual structure of mathematics education research originating from Turkey. According to Van Eck and Waltman (2014) and Perianes-Rodriguez et al. (2016), using a fractional counting method should be preferred rather than using a full counting method while conducting the co-citation analysis due to the fact that it reduces the impact of publications with a long reference list within the construction of co-citation network. For the 416 publications included in the co-citation analysis, the minimum number of co-citations that an author received was set to 20. Out of 9762 authors, 73 authors satisfied this threshold to be included in the co-citation network. As seen in Figure 9, the authors co-cited from the same publications were grouped into 7 different clusters. Authors who get more co-citations incline to be closer to each other in the visualization. Of these 7 clusters, 4 clusters have relatively more significant size than others.

Figure 9
Network Visualization for Co-cited Authors



A visualization of the co-citation network shown in Figure 9 reveals that the most co-cited authors or institutions are the National Council of Teachers of Mathematics (NCTM), Ministry of National Education (MoNE, Turkey), R. Lesh, A. Baki, and D. L. Ball. All books, classroom resources, principles and standards for mathematics education published by NCTM and its position statements for mathematics education and all books, reports, and national curriculums related to mathematics education published by MoNE are important knowledge bases for mathematics research in Turkey. Moreover, it is seen that R. Lesh's research on mathematical modeling and problem solving, A. Baki's studies related to teacher education and computer-aided mathematics teaching, and D. L. Ball's research on what knowledge types needed for mathematics teaching have made significant contributions to the knowledge base of mathematics education.

The red cluster that is largest and located at the center of the visualization consists mainly of authors studying on the contemporary approaches, theories, and advanced research in mathematics education (e.g., B. Guven, O. Birgin, and S. Olkun), and qualitative research methods, techniques, and analysis (e.g., A. Saban, A. Yıldırım, J.W. Creswell, L. Cohen, M. B. Miles, and M. Q. Patton). In addition, the research of authors in the red cluster focus on teaching mathematics and geometry (e.g., A. Baki, B. Guven, S. Olkun, Z. Toluk-Ucar, and J. Vande Walle), technology integration in mathematics education (e.g., A. Baki, and B. Guven), and teacher education and curriculum development (e.g., B. Güven).

The green cluster in the visualization substantially includes studies focused on quantitative and/or mixed research methods (e.g., N. Karasar, M. Peker, and S. Büyüköztürk), measurement and evaluation in education (e.g, Y. Baykul), development of scale (e.g., M. Baloğlu), and statistics (e.g., J. Cohen, and R. B. Kline). Additionally, some authors in this cluster are interested in research topics concerning self-regulation (e.g., B. J. Zimmerman), self-beliefs (e.g., M. F. Pajares), motivation, attitude, anxiety, fear of mathematics (e.g., M. Baloglu), mathematical achievement, mathematical literacy (e.g., M. Altun), social learning theory (e.g., A. Bandura) and social constructivism (e.g., P. R. Pintrich). Thus, it can be said that the authors' studies in the green cluster form an intellectual knowledge base for conducting quantitative or mixed research using statistical methods in mathematics education.

While considering the authors' research in the blue cluster, the prominent studies cover the topics over mathematical or algebraic thinking (e.g., T. P. Carpenter), mathematical reasoning (such as algebraic, fractional, multiplicative, quantitative, spatial or geometrical reasoning), and teaching algebra (such as fractions, place values, multiplication, division, addition and subtraction). Other research of interest to the authors in this cluster are: improving mathematics teaching and learning (e.g., H. James), instructional design, development and evaluation of learning trajectories (e.g., D. H., Clements and M. T. Battista), constructivism (e.g., J. Piaget, P. Cobb and L. P. Steffe), students' learning needs and equity issues in mathematics education (e.g., M. Stephan, P. Cobb, and M. T. Battista), and developing realistic mathematics education (e.g., K. Gravemeijer). In other words, the authors in the blue cluster contribute by forming an intellectual knowledge base for mathematics education research in Turkey with regards to research areas on mathematical thinking, mathematical reasoning, teaching fractions, developing students' mathematical competences, teacher education and professional development.

The yellow cluster in the visualization consists considerably of authors' studies concentrating on pedagogical content knowledge (e.g., L. Shulman), mathematical knowledge for teaching (e.g., A. G. Thompson, D. L. Ball, and H. Hill), teachers' professional noticing (e.g., E. A. van es, M. G. Sherin, and V. R. Jacobs), students' mathematical knowledge, teachers' professional development and mathematical problem solving (e.g., A. H. Schoenfeld). Therefore, it can be easily seen that the authors in this cluster particularly are an important knowledge base for the studies on mathematics teaching for knowledge and mathematics teacher noticing.

The purple cluster in the visualization illustrates that the studies of the authors in this cluster focus heavily on mathematical modeling and mathematical problem solving. (e.g., G. Kaiser, H. M. Doer, L. D. English, L. V. Verschaffel, R. Lesh, and W. Blum). On the other hand, the research studies of the authors in the turquoise cluster cover the topics regarding the relationship between mathematics education and culture, social and cultural perspectives in mathematics education, history and philosophy of mathematics education, values in mathematics teaching (e.g., A. J. Bishop, P. Ernest, S. DurmuS, Y. Dede, and W. T. Seah). Finally, the orange cluster in the visualization consists of authors working on educational psychology (e.g., D. W. Johnson, and R. E. Slavin).

5. Discussion and Conclusion

In this study, we determined the leading authors, institutions and publications for mathematics education research in Turkey. In addition to this, we described the topics the authors frequently delved into, which topics need to be more studied, and which topics would be popular in future research with the use of performance analysis and science mapping. At the same time, we visualized the intellectual structure of mathematics education research in terms of authors co-citation network to illustrate which seminal authors Turkish mathematics education scholars utilized for their research study.

Our first results related to the trends of the total number of publications between 2005 and 2021 show that the total number of publications per year regularly increased until 2012; however, it generally decreased after 2012 although there were some fluctuations. The total number of citations per year follows almost the same pattern as the total number of publications per year until 2018. Contrary to our findings, Özkaya (2018), examining the social structure and scientific knowledge of mathematics education research at the international level, found that the total number of publications per year continuously increased for each 5-years period between 1980 and 2018. In a similar study conducted by Gökçe and Güner (2021), investigating trends of SSCI-indexed publications in the field of mathematics education between 1980 and 2021, it was found the same results. Specially, the results for both studies indicated that the increase rate of the total number of publications after 2004 accelerated upwards by almost doubling it in previous 5-years periods. Huang et al. (2020) studied on the changes of cognitive structure of educational research across three different time range and found that the total number of publications regularly increased after 2007. On the other hand, Gülmez et al. (2020) probed the publications related to educational research stemmed from Turkey with the use of bibliometric analysis. Their results indicated parallelism with our findings. They found out the total number of publications expeditiously increased from 2007 to 2017, however it started to decrease after 2017. As can be seen from these studies, while the number of publications in mathematics education and education research in the world has increased over the years, our findings have revealed that those addressed in Turkey have decreased since 2012. The reason for this decrease may be due to the fact that some journals from Turkey were excluded from the SSCI index (such as Hacettepe University Journal of Education and Energy Education Science and Technology Part B: Social and Educational Studies).

Our findings show the most productive and influential institution in the field of mathematics education in Turkey is METU. Although Gazi University is in the third place in terms of productivity, it is in the 10th place regarding effectiveness in the field (see Table 3). The reason for this situation may be considered because of international collaborative publications of authors in METU get high number of citations (see Figure 3- 4). While Karadeniz Technical University (KTU) is the second most influential university, its productivity is in the 4th order. Given KTU's average year of publications is 2012 and the decrease in its productivity, this stems from its College of Education was taken from KTU and connected to the newly established Trabzon University. Hacettepe University is the most productive second university as well as it is the most effective third university. Gülmez et al. (2020) obtained the similar results to us. They found that the leading institution of educational research in Turkey is METU. In opposite to the current study, the other most influential universities are Hacettepe University and KTU, respectively. Similarly, even though Gazi University is the most productive third university, its impact in the educational studies field falls behind its the counterparts.

The findings also revealed that the most impactful authors in the field are A. Baki, B. Guven, and D. Akyuz. In terms of productivity, the authors, M. Isıksal-Bostan, A. Kursat Erbas, and O. Birgin, have a large number of publications. It is also seen that M. Isıksal-Bostan and D. Akyuz have the most up-to-date publications (see Table 2). Considering the publications, D. Akyuz's article with M. Stephan is the most remarkable and influential in the field. Another striking point is that A. Baki has three articles, and D. Akyuz has two articles within the most influential 15 articles in the field. The results also show that 4 articles within the influential articles were published jointly with foreign authors (see Table 4). This is not surprising since Bordons et al. (2015) found that international co-authored publications have a higher impact than others on social science research. In this context, we can say that supporting international collaborative studies in mathematics education will increase both the quality of the publication and the effectiveness of the field. In addition, 7 of 15 effective articles are quantitatively-weighted research, and 4 are literature reviews. Similar to the results found by Gülmez et al. (2020), we can say statistical methods have a significant position for mathematics education research as in educational research in Turkey.

Conceptional mapping and performance analysis indicate that the most studied topics of mathematics education research in Turkey are mathematics achievement, mathematical modeling, and attitude. The topics needed to be more studies are function and functional thinking, anxiety in mathematics education, proportional reasoning, spatial ability, problem-based learning, and gender. It is seen that the most remarkable and effective subjects in the field are meta-analysis, mathematical problem solving, and self-efficacy. Recent trendy topics are noticing, structural equation modeling, and proportional reasoning. In this context, it can be said that the studies particularly focusing on trendy topics would receive significant citations and be influential in the field. Gökçe and Güner (2021) stated the most popular themes in mathematics education research between 2005 and 2020 are curriculum, achievement, reform in mathematics education, professional development, teacher education, measurement and evaluation, multivariate analysis techniques, equality and educational policies. In this regard, studies carried out on mathematics education in Turkey also show parallelism to studies in the world.

Examination deeply the author co-citation map shows the publications stemmed from Turkey utilized the seminal authors whose studies majorly focus on the professional development of mathematics teachers (teacher education, noticing, MKT and PCK), teaching and learning mathematics, curriculum development, statistical research methods, educational research methods, mathematical modeling and problem solving, mathematical thinking and reasoning. Furthermore, they benefited from the studies on the philosophy, history, and culture of mathematics, learning theories, and educational psychology.

Although the results of the current study provide useful information to researchers, academicians, program developers, policy makers, and doctoral and master students regarding the trends of the publication, research gaps, popular concepts, and influential authors and publications in the field, but it has some limitations. The first limitation is the findings of the current study only depends on the bibliometric data obtaining through our selection criteria for publications. Another limitation is the inability to use the bibliometric data of publications that are not in the WoS database in our analysis. In future studies, bibliometric data can be obtained from alternative databases such as Microsoft Academic, Dimensions and/or Scopus and it may integrate into the bibliometric data of the WoS database. Thus, it can be obtained more extensive results. In addition, citation-based indicators (e.g., average citation, normalized citation and average normalized citation scores) could be biased and manipulated by self-citation of an author or research team (Zupic & Cater, 2015). Such a situation may have negatively affected the results of the current study. In order to obtain more precise results, new studies can be conducted by extracting self-citation. The other limitations of this study may be derived from the limitations of the WoS database and VOSviewer software. The limitations of WoS and VOSviewer may affect the result of this study. For example, the VOSviewer software only includes the first author of a cited document for co-citation analysis, which may cause other authors to be underestimated in the analysis.

Future studies can be done on more specific topics in mathematics education such as teaching algebra, teaching geometry, teaching of statistics and probability, teaching number sense or patterns, mathematical problem solving and mathematical modelling. In addition, publications in ESCI, AHCI, SCI and/or SCI-expanded indexes may be included in future studies as well as SSCI indexed publications. Furthermore, the use of other qualitative or quantitative methods such as meta-analysis, meta-synthesis and systematic literature review together with the bibliometric analysis method in future studies may provide a more in-depth and comprehensive examination of their results.

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