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GeoGebra in Educational Research: A Bibliometric Analysis

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Abstract

This study aimed to investigate research trends regarding the use of GeoGebra in educational research through bibliometric analysis. 301 articles published in the Web of Science database between 2009 and 2023 were included in the research. Web of Science database and VOSviewer program were used during bibliometric analysis. Performance analysis and scientific mapping techniques were used in the analysis of the data obtained by the bibliometric analysis method. Articles were analyzed according to their years and citation, country of origin, authors, index of journals, journals, co-authorship of authors, co-occurrence of author keywords, citation of authors, and citation of countries. Research results show that in recent years, researchers have tended to research GeoGebra software in the field of education. The results of publication and citation analyses for authors, countries, and journals will help researchers and educators to have an idea about current GeoGebra research trends and provide preliminary information for future studies.

Introduction

In the 21st century, educational processes have undergone rapid change all over the world, and technological developments have been more integrated into learning processes. Moreover, considering that new-generation students frequently use technological tools, integrating technology into the learning process has become inevitable. The most common software for technology integration in education is GeoGebra (Gökçe & Güner, 2022). GeoGebra was designed as part of Markus Hohenwarter's Master's Thesis project at the University of Salzburg in Austria, which started in 2001 (Hohenwarter & Lavicza, 2007; Preiner, 2008). Hohenwarter stated that this project aims to develop a completely new tool for mathematics education in secondary schools with the idea of combining the ease of use of dynamic geometry software with the power and capabilities of a computer algebra system. (Preiner, 2008). The development of GeoGebra was not limited to the master's thesis project but continued rapidly within the scope of Hohenwarter's doctoral thesis supported by the Austrian Academy of Sciences (Hohenwarter & Fuchs, 2004; Preiner, 2008).

Although GeoGebra was developed for mathematics education, it attracts great attention from many researchers from different fields. Academic studies using GeoGebra software are carried out in many fields such as architecture (e.g., Di Paola et al., 2015; Zamboj, 2018), economics (e.g., Miletic & Lesaja, 2016; Sanchez, 2013), engineering (e.g., Attorps et al., 2015; Zamora, 2020), computer science (e.g., Gergelitsova & Holan, 2012;

Trelles-Zambrano et al., 2019), psychology (e.g., Simon et al., 2022; Xing et al., 2015), veterinary medicine (e.g., De Felice et al., 2020), health (e.g., Gursoy et al., 2021).

With the increasing popularity of the software, the question of why is different about GeoGebra has been raised. GeoGebra software has many functions that make it different from other software. A major factor in the growing community around GeoGebra is that the software is free (Edwards & Jones, 2006) and open source (Preiner, 2008). GeoGebra has attracted many visitors all over the world due to its web accessibility and user-friendly interface (Bu & Schoen, 2011).

GeoGebra is a versatile tool that combines the features of Computer Algebra System (CAS) and Dynamic Geometry Software (DGS) (Hall & Chamblee, 2013). GeoGebra Software simultaneously presents mathematical information on a worksheet in graph view, table view, and algebra view windows (Hohenwarter & Hohenwarter, 2009). Moreover, the software dynamically interconnects all representations of mathematical knowledge (Dikovic, 2009). A change in the mathematical information causes a change in its representation in other windows (Hohenwarter & Hohenwarter, 2009).An important feature of GeoGebra software is that it is Java-based and can run on all operating systems (Hohenwarter & Lavicza, 2007; Preiner, 2008). Interactive HTML worksheets, which are dynamic materials, can be created in the software, and the materials can be used in any browser with Java-based internet support without having GeoGebra software installed (Hohenwarter & Fuchs, 2004). Volunteers from the GeoGebra user community have translated the software into many different languages for use in local languages and multicultural environments (Hohenwarter & Lavicza, 2007). Another feature that the software offers to users is the construction protocol that gives the step-by-step process of creating objects (Hohenwarter & Fuchs, 2004).

The use of GeoGebra has many benefits in education. GeoGebra gives students and teachers the opportunity to individualize learning (Dikovic, 2009). It can enable students to participate in activities where they will use their higher-level thinking skills at the highest level (Edwards & Jones, 2006). The combination of the CAS and the DGS allows students to increase their cognitive abilities (Dikovic, 2009). It helps students externalize their mental models (Bu & Schoen, 2011). It can motivate students by visually representing various mathematical concepts and the relationships between concepts in a dynamic way.

The benefits of GeoGebra software in the educational process have attracted the attention of many researchers and GeoGebra has been the subject of numerous educational studies (e.g., Demir & Zengin, 2023; Graeme Welch & Ponce Campuzano, 2023; Lognoli, 2017; Mushipe & Ogbonnaya, 2019; Zhang et al., 2023). When educational researches are examined, it is seen that studies are carried out on primary (e.g., Arzarello et al., 2012; Çetin et al., 2015), secondary (e.g., Şeker & Erdoğan, 2017; Ünsal & Cenk, 2020) and university (e.g., Dikovic, 2009; Owusu et al., 2023) levels of education. There are also studies using the GeoGebra software in different disciplines of education such as physics (Solvang & Haglund, 2021; Walsh, 2017), chemistry (Liguori, 2017), biology (Sönmez & Özgün-Koca, 2020).

The large number of scientific studies on GeoGebra software in an educational context has led researchers to examine these studies. In the literature, there are many review studies on the integration of GeoGebra into mathematics education (e.g., Lestari et al., 2023; Morales Chicana et al., 2023; Munante-Toledo et al., 2021; Ng ve Rosli, 2023; Yohannes & Chen, 2023). In addition, meta-analysis studies were conducted to evaluate the main effect of GeoGebra on variables such as students' mathematics learning (Zhang et al., 2023), mathematical abilities (Anzani & Juandi, 2022; Juandi et al., 2021), mathematical creative thinking skills (Rachmawati et al., 2023), higher order thinking skills (Haryati, 2022). One of the methods that provides the opportunity to examine studies in the literature is the bibliometric analysis method. Bibliometric analysis offers the opportunity to explore and analyze large volumes of data that can be used to identify research components, collaboration patterns, and emerging trends on a research topic (Castañeda et al., 2022).

When the literature was examined, it was determined that a limited number of bibliometric analyses were conducted to determine the usage trends of GeoGebra software. In Supriadi et al.'s (2022) study, a bibliometric analysis of 131 studies on GeoGebra in the Scopus database was conducted to determine the development of GeoGebra software in Indonesia. Similarly, Maulidiya et al., (2023) conducted a bibliometric analysis of 309 articles published in Indonesian journals between 2012 and 2022. Gökçe and Güner (2022) carried out a bibliometric analysis study in order to determine the trends of mathematics education studies related to GeoGebra published in the Web of Science database between 2009 and 2021. In the research, it was determined that studies on GeoGebra have a four-clustered structure: Teaching analytics, Learner anatomy, Technological focus, and Conceptual extension.

It can be seen that two of the bibliometric studies (Maulidiya et al., 2023; Supriadi et al., 2022) presented above include only studies in Indonesia, while the other (Gökçe & Güner, 2022) focuses only on GeoGebra studies in mathematics education. Over the years, the lack of bibliometric studies that reveal what kind of studies have been conducted on GeoGebra in all educational research has attracted attention. This study aimed to investigate the usage trends of GeoGebra in education through bibliometric analysis. Articles indexed in the Web of Science (WoS) database were examined by publication years and citation, country of origin, authors, index of journals, journals, co-authorship of authors, co-occurrence of author keywords, citation of authors, citation of countries. Thus, researchers can obtain information about research trends, countries, journals and authors in the use of Geogebra software in education, see research gaps more effectively with keyword analysis and obtain new information for future studies.

Method

The bibliometric analysis method was used in this research. Bibliometric methodology involves the use of quantitative techniques on bibliometric data (e.g., publication units and citations) (Donthu et al., 2021). A total of 925 studies were reached by searching the WoS database with the keyword "GeoGebra" in all fields on December 8, 2023. Since it was aimed to examine the studies in which GeoGebra software was used in educational research, documents in the education category were selected and access to 641 studies was provided. Among these studies, articles published in peer-reviewed journals were selected and 399 articles were reached. Finally, the article language was selected as English, and 303 articles were obtained. It was understood that 2 of them were not related to GeoGebra and were excluded from the data set. As a result of the restrictions, 301 articles were studied. 19 of 301 articles were published in various journals as early access. The data collection process is presented in the Table 1.

Table 1. Data Collection Process

Step	**Process**
Step 1	Records identified through database searching: Web of Science Core Collections were searched with the keyword “GeoGebra” in all fields selection (n = 925)
Step 2	Web of Science categories were limited = (“Education & Educational Research”, “Education Scientific Disciplines”, “Psychology Educational”, “Special Education” (n=641)
Step 3	Document types were limited as “Article” (n= 399)
Step 4	Language was limited as “English” (n=303)
Step 5	Articles using Geogegbra were included in the bibliometric analysis. (n=301)

There was no year limitation during the search, but the first article in the WoS database was found in 2009. For this reason, GeoGebra articles between 2009 and 2023 were included in the analysis. In the data analysis process, bibliometric analysis was carried out with performance analysis and science mapping techniques (Castañeda et al., 2022; Donthu et al., 2021). While performance analysis takes into account the contributions of research components, science mapping focuses on the relationships between research components (Donthu et al., 2021). With performance analysis, publication and citation metrics (year, citation, country of origin, author, journal, and journal index) were calculated (Donthu et al., 2021). Science mapping was carried out by applying co-authorship of authors, citation of authors, citation of countries, and co-occurrence of author keywords techniques (Castañeda et al., 2022). VOSviewer software was used in the data analysis as it allows visualizing all kinds of bibliometric networks (Van Eck & Waltman, 2014).

VOSviewer provides visualization of large bibliometric maps, making them easier to interpret (van Eck & Waltman, 2010). VOSviewer is a Java-based software that enables the creation of bibliometric networks (www.vosviewer.com). VOSviewer takes a distance-based approach to visualizing bibliometric networks (Van Eck & Waltman, 2014). VOSviewer assigns nodes in a network to clusters, and clusters consist of nodes that are closely related to each other (van Eck & Waltman, 2014). Clusters located close to each other on the map indicate closely related areas (van Eck, 2011; van Eck & Waltman, 2010). The smaller the distance between nodes, the higher the relationship between them (van Eck & Waltman, 2014). VOSviewer uses colors to indicate the cluster to which a node is assigned (van Eck, 2011; van Eck & Waltman, 2010; van Eck & Waltman, 2014; Waltman et al., 2010).

Results

Articles by Publication Years and Citation

Citation statistics of 301 articles containing GeoGebra software in educational research published in the WoS database between 2009 and 2023 were examined. The total number of articles citing 301 articles is 1,005. The total number of citations received by the articles is 1,518. When the authors' self-citations are excluded, the total number of citations is 1,137 and the average number of citations of the articles is 5.04. The distribution of articles according to the year they were published is presented in Table 2 and citation statistics of the articles by publication years are presented in Figure 1.

Table 2. Distribution of Articles by Publication Years

Year	N	%
2009	3	0.997
2010	7	2.326
2011	9	2.990
2012	6	1.993
2013	25	8.306
2014	7	2.326
2015	22	7.309
2016	16	5.316
2017	22	7.309
2018	24	7.973
2019	29	9.635
2020	32	10.631
2021	35	11.628
2022	33	10.963
2023	31	10.299

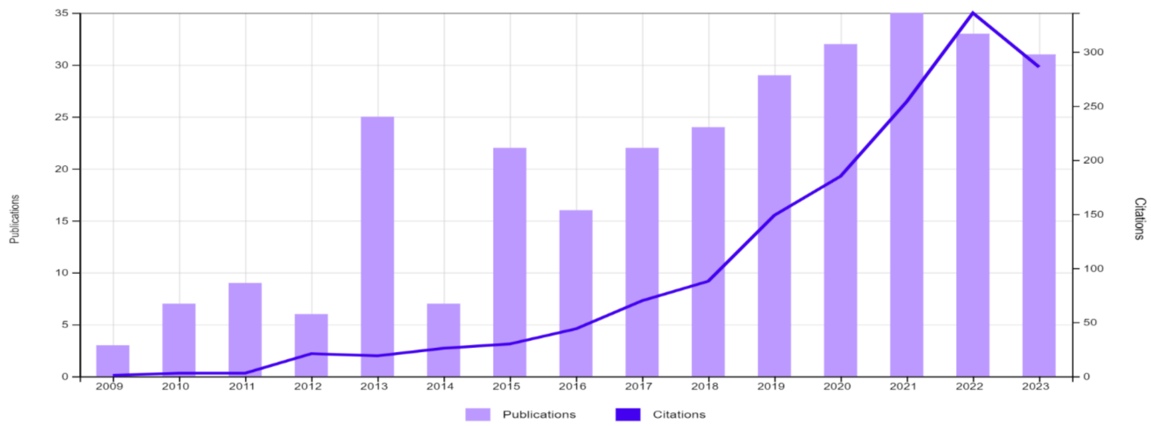

Figure 1. Citation Statistics of Articles

When Table 2 is examined, 301 articles published in a 15-year period between 2009 and 2023 were analyzed. Therefore, it was concluded that the average number of articles published annually was approximately 20. However, it is seen that the average number of publications was not reached in the first 4 years. The most articles belong to 2021, followed by 2022 and 2023, respectively. The fewest articles were published in 2009-2012. The number of articles published in the last five years constitutes 53.156% of all articles. This indicates that interest in the use of GeoGebra software in educational research has increased in recent years. Supporting this finding, as seen in Figure 1, the majority of citations belong to after 2018, the highest number of citations belong to 2022, and the least number of citations belong to 2009, 2010, and 2011. The high number of citations in recent years indicates that articles published in previous years have started to receive citations in subsequent years.

Articles by Country of Origin

The 301 GeoGebra articles originate from 60 countries. The countries from which 5 or more articles originate are presented in the Table 3.

Table 3. Distribution of Articles by Country of Origin

Country	**N**	**%**
Turkey	63	20.93
USA	28	9.302
Serbia	24	7.973
Spain	21	6.977
Israel	19	6.312
Austria	16	5.316
South Africa	15	4.983
England	12	3.987
Czech Republic	10	3.322
Indonesia	10	3.322
Brazil	9	2.990
Italy	9	2.990
Sweden	9	2.990
Mexico	8	2.658
Australia	7	2.326
China	7	2.326
Portugal	7	2.326
Malaysia	6	1.993
Canada	5	1.661
Chile	5	1.661
Finland	5	1.661
Norway	5	1.661
Russia	5	1.661

When the table 3 is examined, the origin country of the most articles is Turkey. This is followed by America, Serbia, Spain, Israel, Austria, and South Africa, respectively.

Articles by Authors

Authors who published 5 or more articles on GeoGebra are Zengin, Yılmaz with 18 (5.980%) articles; Lavicza, Zsolt with 16 (5.316%) articles; Stupel, Moshe with 11 (3.654%) articles; Takaci, Djurdjica with 8 (2.658%) articles; Hohenwarter, Markus with 8 (2.658%) articles; Budinski, Natalija with 7 (2.326%) articles; Tatar, Enver with 5 (1.661%) articles.

Articles by Index of Journals

According to the index analysis in which the articles are published, ESCI ranks first with 226 (75.083%) articles, SSCI ranks second with 68 (22.591%) articles, and SCI-Expanded ranks third with 13 (4.319%) articles.

Articles by Journals

Journals that published 5 or more GeoGebra articles among 81 journals are presented in the Table 4.

Table 4. Distribution of Articles by Journals

Journal	**N**	**%**
International Journal of Mathematical Education in Science and Technology	54	17.940
International Journal for Technology in Mathematics Education	47	15.615
Education and Information Technologies	15	4.983
International Journal of Science and Mathematics Education	9	2.990
Teaching Mathematics and Its Applications	9	2.990
European Journal of Contemporary Education	8	2.658
International Electronic Journal of Mathematics Education	7	2.326
International Journal of Emerging Technologies in Learning	7	2.326
International Journal of Instruction	7	2.326
Mathematics and Informatics	7	2.326
Computers in the Schools	6	1.993
Interactive Learning Environments	5	1.661
Journal of Mathematical Behavior	*5*	1.661
Zdm Mathematics Education	*5*	1.661

When the Table 4 is examined, the high number of GeoGebra articles published in the International Journal of Mathematical Education in Science and Technology and the International Journal for Technology in Mathematics Education is remarkable.

Co-authorship of Authors

Co-author analysis connects authors who wrote the article together (Yılmaz, 2021). The collaboration of two authors can be measured by the number of articles they write together (Van Eck, 2011). There are a total of 561 authors in 301 GeoGebra articles. In the co-author analysis; authors with at least 1 article and 1 citation were included in the analysis, and 429 authors met the threshold value. Additionally, authors who are not linked with other authors have been removed from the network graph. As a result of the analysis, the largest set connected of links consists of 34 items and 9 clusters [number of links: 81, total link strength: 101]. While number of links shows the number of authors collaborated, total link strength shows the total frequency of collaboration. Figure 2 presents collaboration network map of the 34 most connected authors.

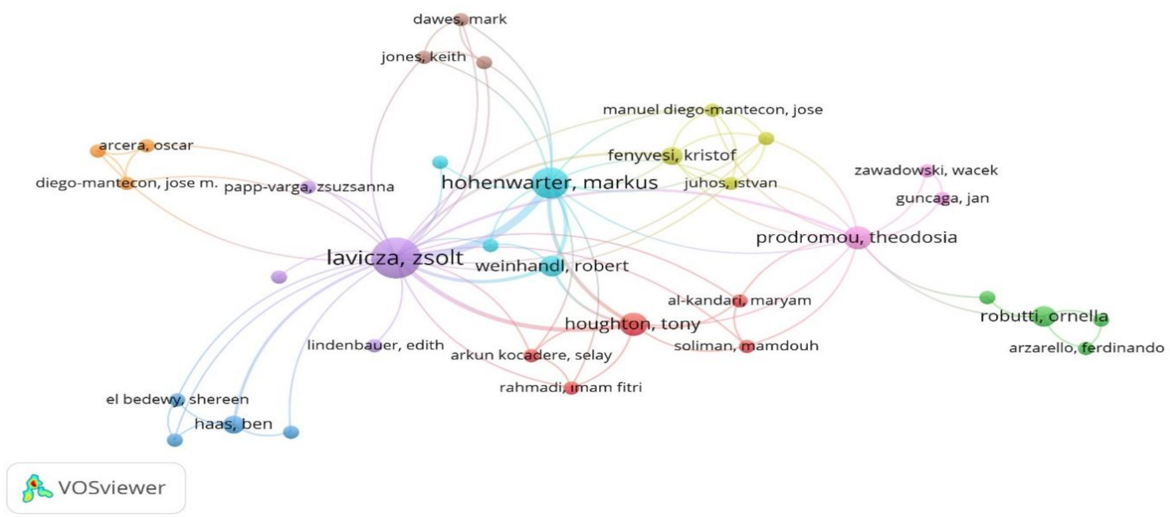

Figure 2. Collaboration Network Map

When Figure 2 is examined, it is seen that some authors are clustered among themselves and that these clusters have collaboration ties with other clusters. The thickness of the edges between two nodes shows the frequency of the two authors' collaboration, and as the frequency increases, the thickness increases. Nodes of the same color, that is, in the same cluster, link more with each other. The sizes of the nodes indicate the frequency of link. In addition, nodes in the same cluster getting closer to each other is an indicator of increased cooperation frequency.

According to VOSviewer results, there are 3 to 5 co-authors in 9 different clusters. Among these authors, Lavicza, Zsolt [links: 27, total link strength: 42], Hohenwarter, Markus [links: 15, total link strength: 26], Prodromou, Theodosia [links: 13, total link strength: 14] and Houghton, Tony [links: 8, total link strength: 14] are more prominent in co-authorship.

Co-occurence of Author Keywords

There are a total of 775 keywords in 301 articles. Most occurred (10 and more) keywords of GeoGebra articles are “GeoGebra” (n=125), “dynamic geometry software” (n=15), “mathematics education” (n=15), “dynamic mathematics software” (n=14), “mathematics” (n=13), “geometry” (n=12), “technology” (n=12), “calculus” (n=10). Most occurring keywords of GeoGebra studies are presented in Table 5.

Table 5. Most Occurred Keywords of GeoGebra Articles

Keywords	Occurrences
geogebra	125
dynamic geometry software	15
mathematics education	15
dynamic mathematics software	14
mathematics	13
geometry	12
technology	12
calculus	10

The number of co-occurrences of two keywords together is the number of articles in which both keywords appear together in the author keywords list (van Eck & Waltman, 2014). To create the co-occurrence of author keywords network map, the minimum number of repetitions of a keyword is determined as 3 and 49 keywords met the threshold. Figure 3 presents co-occurrences network map of the 49 most connected author keywords.

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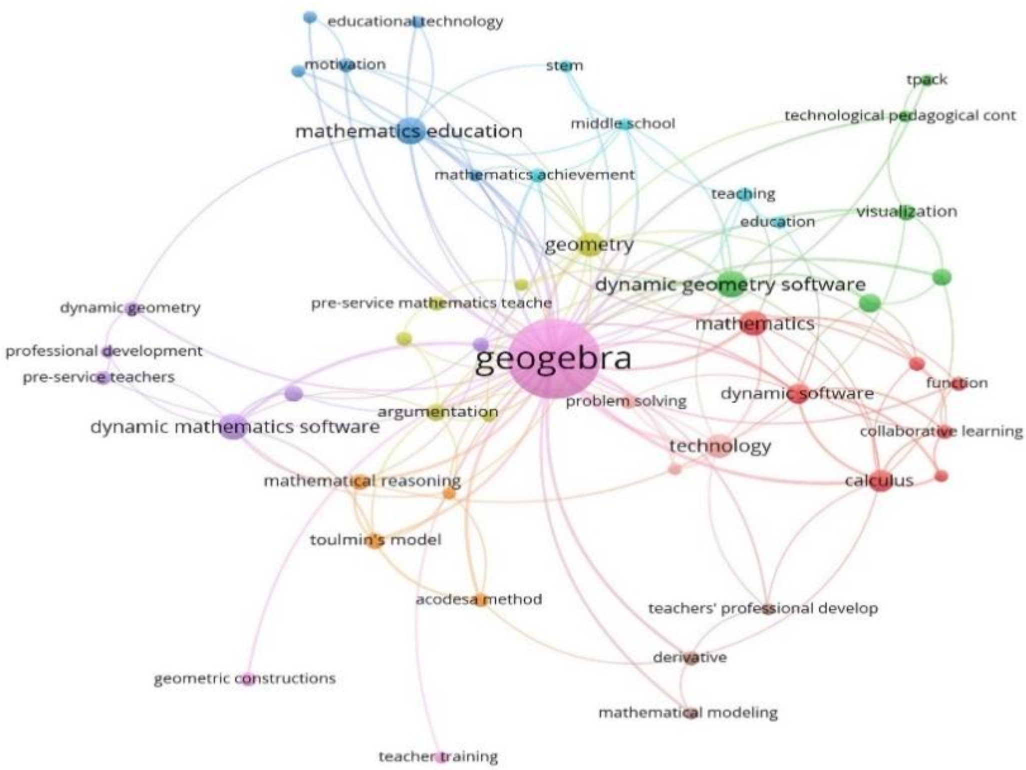

Figure 3. Co-occurrences Network Map of Author Keywords

When co-occurrences network map of author keywords is examined, the keyword with the most links is “GeoGebra” [links: 44, total link strength: 124]. It is seen that the other keywords with the most links in articles are: "Geometry" [links: 14, total link strength: 22], "Mathematics Education" [links: 11, total link strength: 19], "Dynamic Geometry Software" [links: 12, total link strength: 17], "Mathematics" [links: 10, total link strength: 15], and “Calculus” [links: 10, total link strength: 19]. In addition, in places where link is low, keywords related to teacher education such as "teachers' professional development", "tpack", "technological pedagogical content knowledge", "pre-service teachers", "teacher education", "teacher training" attract attention.

Citation of Authors

Citation analysis of the 429 authors was examined. From 429 authors with at least 1 article and 5 citations, the largest set connected of links consists of 152 items and 14 clusters for citations [number of links: 529, total link strength: 719]. The authors' citation network map is presented in Figure 4.

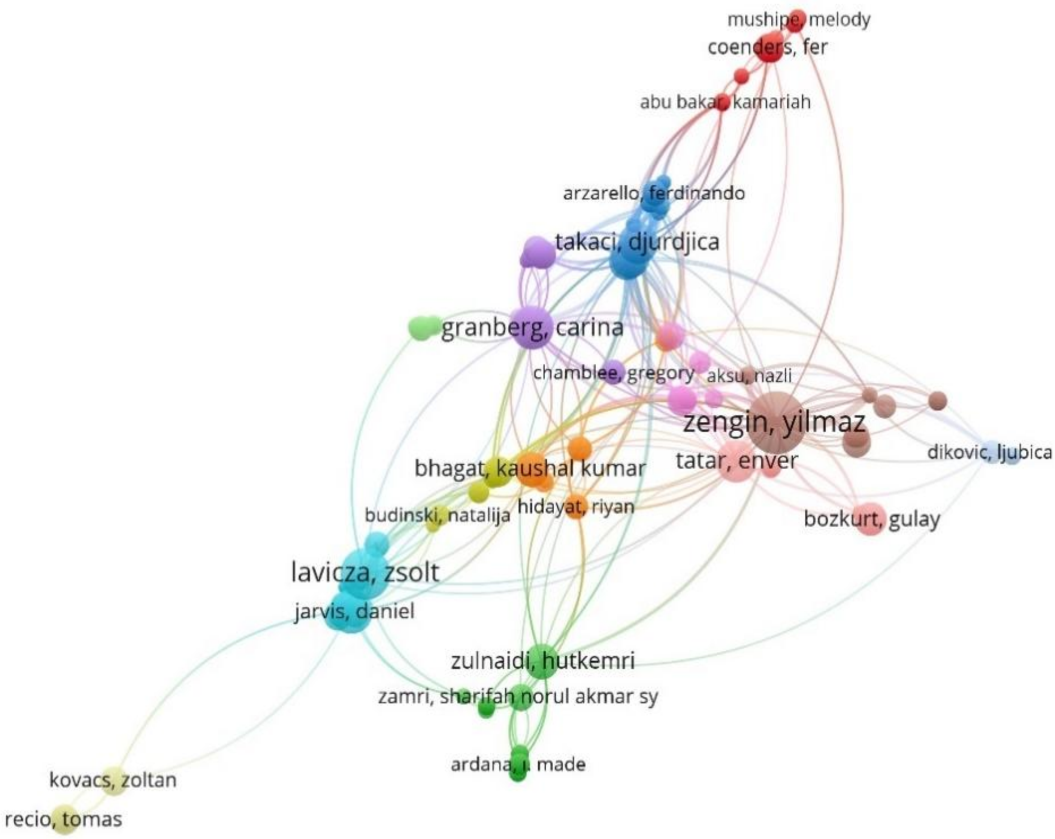

Figure 4. Authors' Citation Network Map

When the Figure 4 is examined, the first five authors with the most citations are Zengin, Yilmaz [citation= 164, article=18], Lavicza, Zsolt [citation= 103, article=16], Granberg, Carina [citation= 71, article=3], Hohenwarter, Markus [citation= 68, article=8], Tatar, Enver [citation= 61, article=5] respectively.

Citation of Countries

301 articles originate from 60 countries. In the citation of countries using VoSviewer software; countries with at least 1 article and 5 citations were included in the analysis, and 40 countries met the threshold value. As a result of the analysis, the country group with the largest set connected of links consists of 35 items and 7 clusters [number of links: 155, total link strength: 329]. Countries' citation network map is presented in Figure 5.

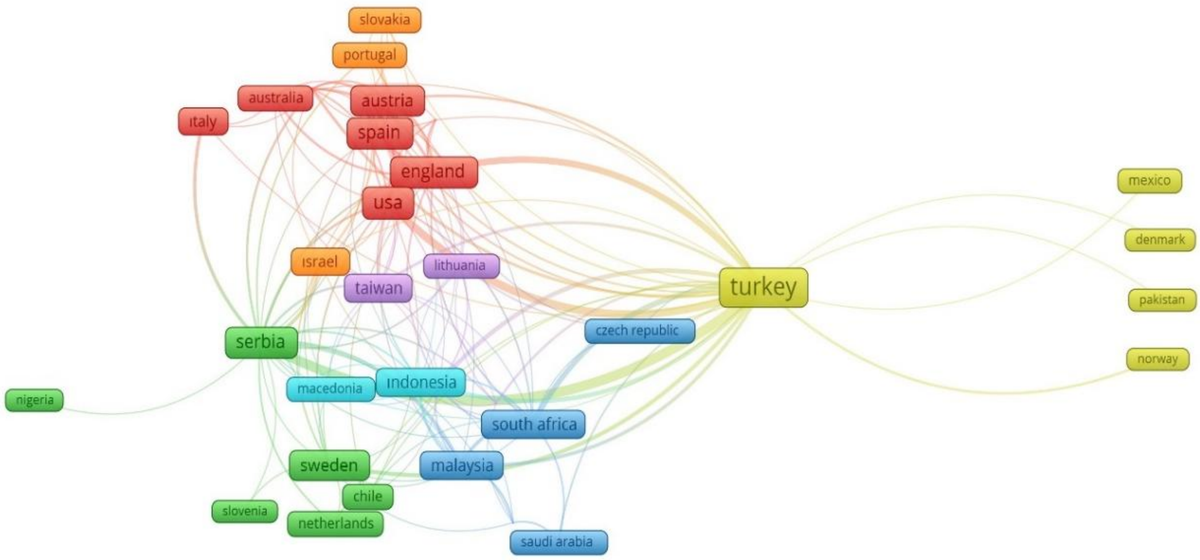

Figure 5. Countries' Citation Network Map

Figure 5 is examined, the countries with the most citations are Turkey [citation= 392, article=63], USA [citation= 136, article=28], England [citation= 129, article=12], Serbia [citation= 124, article=24], and Spain [citation= 112, article=21], respectively.

Discussion and Conclusion

This study examined research trends regarding the use of GeoGebra in educational research using bibliometric analysis. Although there are some bibliometric studies examining the use of GeoGebra in education (Gökçe & Güner, 022; Maulidiya et al., 2023; Supriadi et al., 2022), this research is not limited to studies conducted in a certain country or for a certain discipline and discussed GeoGebra studies in education from a broad perspective. GeoGebra articles in educational research published in WoS between 2009 and 2023 were included in the analysis. When the distribution of articles by years is examined, there is no year in which an article was not published in the 15 years. Although in some years there was a decrease compared to the previous year, the number of articles increased again in the following year. It is seen that the highest number of articles belongs to 2021 and the least to 2009. The fact that the number of articles published in the last five years is more than half of all articles and that the articles have received many citations shows that the interest in the use of GeoGebra software in educational research has increased in recent years. When the citation statistics of the articles are evaluated, the highest number of citations belongs to 2022 and the lowest number of citations belongs to 2009, 2010, and 2011. The number of citations has been high in recent years because the number of citations of articles from previous years has increased over the years.

When the authors of the articles are examined, the top three authors with the highest number of articles among 561 authors are Zengin, Yılmaz from Turkey, Lavicza, Zsolt from Austria, and Stupel and Moshe from the United States. When the distribution of the number of articles by country of origin is examined, it is determined that Turkey ranks first among 60 countries with the number of GeoGebra articles in educational research and the number of publications is quite higher compared to other countries. When the authors of the articles are examined, Zengin, Yılmaz from Turkey come first with the highest number of articles among 561 authors. It appears that there is a significant relationship between the number of articles by authors and the countries of origin.

The result of the research is that the majority of articles are published in the ESCI index, followed by SSCI and SCI-E, respectively. When the journals in which the articles were published are examined, the International Journal of Mathematical Education in Science and Technology and the International Journal for Technology in Mathematics Education are the journals that publish the most GeoGebra articles in educational research, publishing approximately one-third of the total articles. The fact that the two journals that publish the most articles are mathematics education journals is proof that GeoGebra software is frequently used in mathematics education. Apart from these, GeoGebra articles have been frequently published in education and technology journals such as the Education and Information Technologies, the European Journal of Contemporary Education, the International Journal of Emerging Technologies in Learning.

In the author's collaboration of the articles, the first is Lavicza, Zsolt, the second is Hohenwarter, Markus and the third is Prodromou, Theodosia. Only two of the top 10 authors who have the most articles (Lavicza, Zsolt, and Hohenwarter, Markus, respectively) are included in the collaboration network map of the 34 most connected authors. This shows that the majority of authors with a high number of articles are not in the top ranks in author collaboration. Although most articles originate from Turkey, it can be said that Turkish writers lag in author collaboration.

According to the research result, the most frequently used author keyword is “GeoGebra”. It is an expected result that the most frequently used keyword in GeoGebra articles is “GeoGebra”. Also, since GeoGebra is a dynamic mathematics/geometry software, the keywords "dynamic geometry software", "dynamic mathematics software" or "dynamic software" are frequently used. Additionally, the frequent use of the words "geometry", "mathematics", and "calculus" indicates that GeoGebra articles are more related to mathematics education. Additionally, among other author keywords, the use of GeoGebra in teacher education research draws attention. It can be said that there is a research trend on the use of GeoGebra in the professional development of teachers and pre-service teachers.

The results of the authors' citation analysis show that Zengin, Yılmaz, Lavicza, Zsolt, Hohenwarter, Markus, and Tatar, Enver, who are also authors with a large number of articles, are the authors with the highest number of citations. On the other hand, Granber, Carina became the third most cited researcher with only three articles. When the citation analysis of the countries is examined, Turkey ranks first in terms of the number of citations as well as the number of articles. Following Turkey in terms of the number of citations are USA, England, Serbia, and Spain, respectively. It is seen that these countries are among the countries with the most publications. Therefore, although there are some exceptions, it is a natural result that more articles are cited more.

Recommendations

This study presents a comprehensive review of GeoGebra research in an educational context. However, the current study has some limitations. First, the results of this study are limited by the WoS database and the "GeoGebra" keyword used. In addition, this research only examines English articles that include GeoGebra software in educational research in the WoS database, which limits the generalization of the results obtained from the research to all GeoGebra studies. Finally, the variables in the bibliometric mapping analysis are limited to the analysis of the VOSViewer program. Researchers can reach more general conclusions about GeoGebra in bibliometric analysis by including databases such as Scopus, ERIC, EBSCO, etc.; different types of research such as these, conference proceeding, book/book chapter, etc.; studies written in different languages, etc. In this study, only articles involving GeoGebra software in educational research were analyzed, but bibliometric analysis of GeoGebra in other fields such as architectural studies, economics, engineering, psychology, veterinary medicine, health, etc. can be performed. Findings from different fields can be presented comparatively.

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