



GeoGebra Landscape Research in Mathematics Learning

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ABSTRACT

GeoGebra is a software designed to facilitate the teaching and learning of mathematics, aiming to enhance students' comprehension of math concepts through its various digital tools and interactive features. The purpose of this study was to examine the research landscape related to the use of GeoGebra in the learning of mathematics. A descriptive bibliometric analysis method was used in this study. The data was retrieved from the Scopus database. According to the study, the number of publications related to GeoGebra in mathematics learning fluctuates annually. The year 2015 saw the highest number of citations compared to any other year. Turkey is the most influential country in this field. In the 2010–2015 and 2016–2020 ranges, the research focus was almost the same, or in other words, there were no significant differences in keywords. However, in the 2021–2023 range, the research focus has a renewal. Many new keywords have appeared.

Keywords: bibliometric; geogebra; landscape research

INTRODUCTION

Enhancing the quality of human resources requires education (Muhaimin et al., 2022; Muhammad & Yolanda, 2022; Samosir, 2022; Samosir et al., 2020; Yeşiltaş et al., 2010). Education should develop into a search-and-discovery-centered instruction that promotes interaction and cooperation and emphasizes creativity and initiative. These goals are more readily attained if students use ICT in educational settings, and better instructional approaches should be developed to achieve these goals (Septian, 2022; Supriyadi et al., 2022; Takači et al., 2015). A learning media is required in the process of learning mathematics (Widodo & Wahyudin, 2018). Technology has turned into one of the most effective learning and teaching tools for mathematics (Dahal et al., 2022; Harini & Taufiq, 2021; Septian et al., 2022). Digital technologies are expected to affect how mathematics courses are developed and taught (Quinn & Aarão, 2020). This transformation is influenced by students' increasing mobility, access to knowledge, and capacity to manage several tasks. The Internet and information technology have a significant impact on people's lives and educational opportunities (Xie et al., 2020).

There are several software tools available now that can help pupils in being more personally responsible for their own learning. Educators need to be open to accepting current developments and use technology into learning (Andayani et al., 2021; Prayitno et al., 2022). Teachers who are in charge of students' education need to be very aware of how technology is used in the classroom. By emphasizing the key ideas in mathematics, teachers can help students find the subject fun to learn. Students are given the information they need to

compete and operate in a high-tech environment by offering them the opportunity to study and understand mathematics through technology (Zulnaidi & Zakaria, 2012).

A software program for teaching mathematics called GeoGebra conceptualizes and uses dynamic mathematics. GeoGebra is a mathematical software program used in the teaching of several areas in mathematics, such as Geometry, Calculus, and Algebra (Uwurukundo et al., 2020). It is extensively used in middle school and beyond for teaching and learning purposes. GeoGebra is a software program designed for educational purposes, with the primary purpose of making mathematical topics simpler and easier for pupils to understand (Ziatdinov & Valles, 2022).

Previous study on GeoGebra research in mathematics learning has been carried out by Uwurukundo et al., (2020). This study reveals that the majority of studies came to the conclusion that GeoGebra is beneficial for teaching and learning mathematics since it helped pupils grasp the material better and were more interested in studying it. Another research conducted by Hamzah & Hidayat (2022), the study's findings also indicate that achievement, conceptual understanding, motivation, visualization skills, engagement, curiosity, critical thinking ability, mathematical reasoning, and problem solving can all be improved by using the GeoGebra software.

GeoGebra in education trends are always increasing. The number of publications on GeoGebra research in mathematics learning increases year after year (Kusharyadi et al., 2023). This study aims to look at the GeoGebra research landscape in mathematics learning using bibliometric analysis. The statistical technique of bibliometrics is used to analyze publications (Muhammad, Elmawati, et al., 2023; Muhammad, Samosir, et al., 2023; Phoong et al., 2022; Zyoud et al., 2015). Looking at the research landscape of GeoGebra serves several purposes. First, it allows us to understand how this technology has been utilized in the context of mathematics education, along with the major achievements and findings in scholarly literature. Second, analyzing the research landscape helps identify existing knowledge gaps that require further investigation to fill. Third, by studying the research landscape, we can pinpoint recent trends and developments in the use of GeoGebra, as well as best practices in integrating this technology into mathematics teaching. Lastly, researching the landscape helps guide future research directions and more effective implementation strategies, thereby supporting the development of better and sustainable mathematics education. Finding out about the research and capturing the landscape of studies on GeoGebra in mathematics education were the goals of this study.

RESEARCH METHODS

In order to find answers to research issues, the bibliometric analysis research method examines research developments (Phoong et al., 2022; Suherman & Vidákovich, 2022). Bibliometric analysis is a method that examines citation and publication patterns in academic literature. It helps identify influential works, trends in research topics, and patterns of collaboration among researchers. By analyzing citations, publications, and keywords, bibliometric analysis provides insights into the structure and dynamics of scholarly communication within specific fields, aiding in understanding research impact and informing future research directions. The researcher used Scopus for the study when looking for data sources related to GeoGebra in studying mathematics since it is the largest abstract indexing database. The process of refining the collected data involves several stages:

identification, screening, eligibility, and inclusion (Moher et al., 2009). The inclusion criteria used were: 1) publications regarding GeoGebra in mathematics learning 2) publications in the form of articles. A bibliometric study was conducted by the researcher on April 28th, 2023, applying the keywords “GeoGebra” AND “mathematics” AND “education”. Search strategy using the article’s title, abstract, and keywords. As a result of this identification, publication data for 288 articles was obtained. The next step is the screening process, in which the researcher screens according to the criteria, namely, must be in the form of articles. From the results of this screening, 139 publications satisfying the aforementioned requirements were found. The researcher used publish or perish, Microsoft excel and VoS viewer to analyze and visualize the data.

RESULT AND DISCUSSION

Publication Trends

Publications on GeoGebra in mathematics learning, in particular articles, were published between 2010 and 2023. The first document on GeoGebra research in mathematics learning related aspects was published in 2010. Figure 1 below shows a total of 139 articles organized by year of publication.

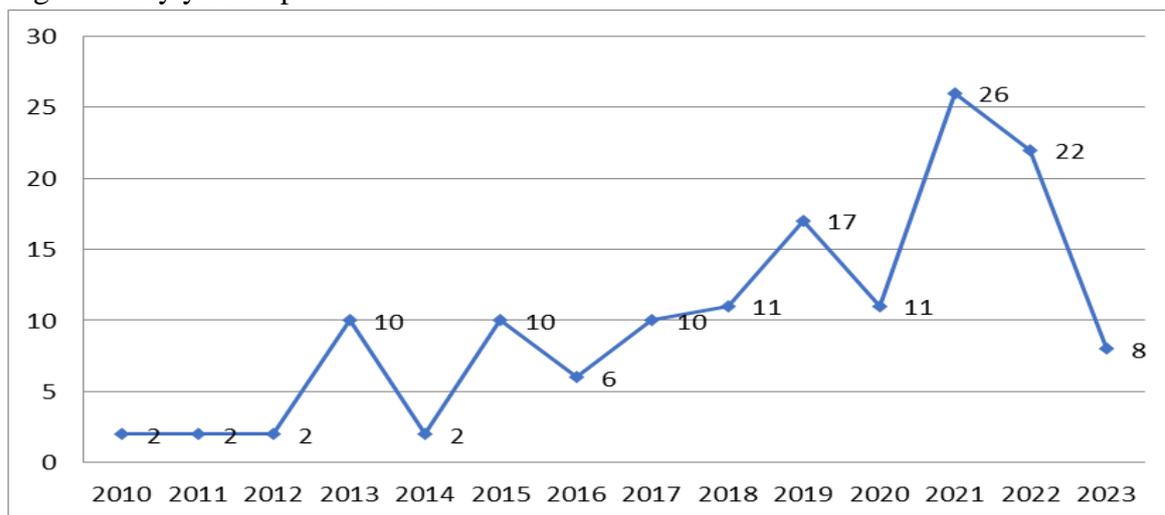


Figure 1. Number of Publications

Figure 1 illustrates that, in comparison to other years, 2021 has had the most amount of publications with 26 documents published. While the quantity of publications from 2010 to 2017 has not changed significantly, the trend line indicates that publications have increased over the last five years. There were only 44 publications between 2010 and 2017, or an average of five documents annually. There were 95 publications between 2018 and 2023, or 15 documents annually on average. The number of publications climbed by 15 between 2020 and 2021, indicating a strong increase in that period.

Most Productive Journals

Figure 2 displays the journals with the highest publication productivity, especially those pertaining to the use of GeoGebra in mathematics education.

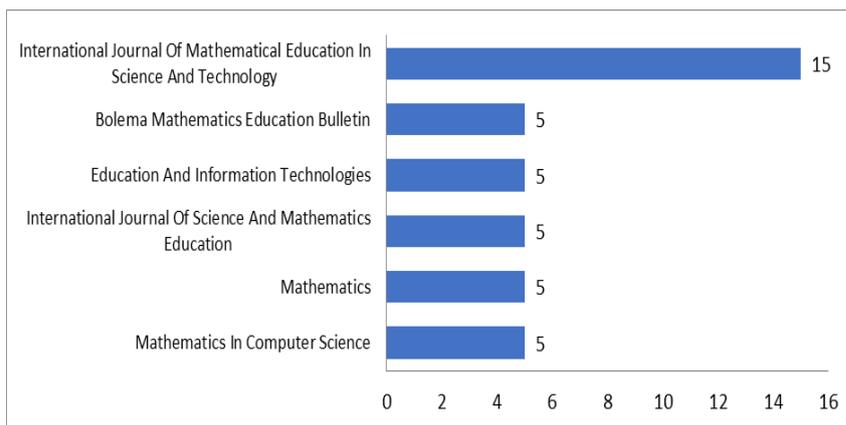


Figure 2. The Most Productive Journal

The most productive journal in research about GeoGebra in mathematics learning, is International Journal of Mathematical Education in Science and Technology with 15 documents. Bolema Mathematics Education Bulletin, Education and Information Technologies, International Journal of Science and Mathematics Education, Mathematics, and Mathematics in Computer Science published five documents each. Other journals publish less than 4 articles.

Authors' Affiliation

Figure 3 displays the research output based on the author affiliation. The top four organizations that contributed the most are shown below.

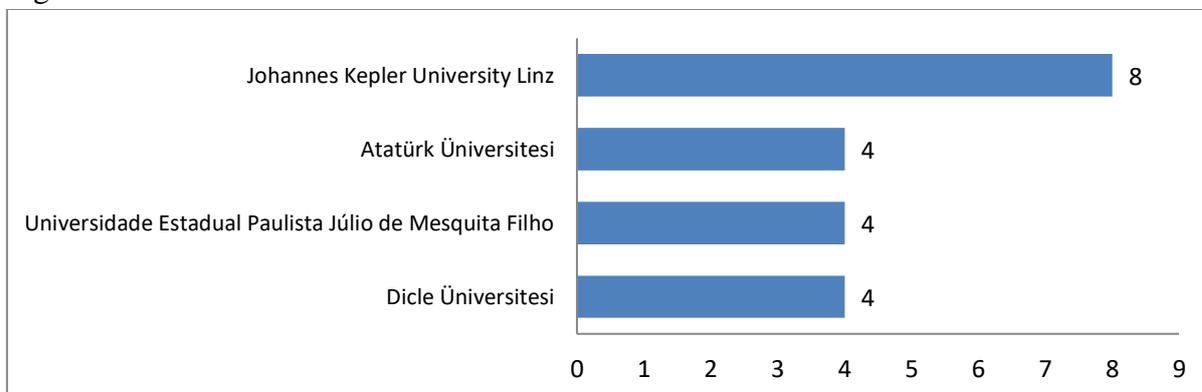


Figure 3. Most Productive Affiliation

Johannes Kepler University Linz (Austria) contributed the most to GeoGebra research in mathematics learning with eight documents. Atatürk Üniversitesi (Turkey), Universidade Estadual Paulista Júlio de Mesquita Filho (Brazil), Dicle Üniversitesi (Turkey) each contributed four documents. Other author affiliations contributed fewer than three documents.

Subject Area Publication Output

Figure 4 displays the research output based on subject area. The top four subject areas related to GeoGebra research in mathematics learning are shown below.

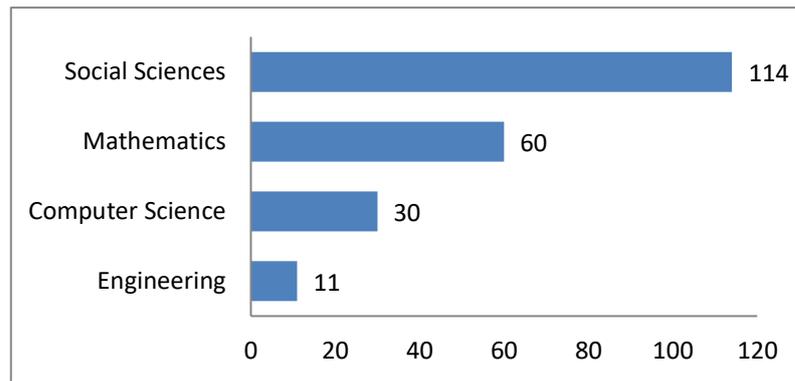


Figure 4. Subject Area Publication Output

Most subject areas are in the social sciences, with a total of 114 publications, or around 43.7%. In second place is the subject area of mathematics, with 60, or 23%, of publications. Next is the subject area of computer science, with 30 or 11.5%. And the last in the top 4 is the subject area of engineering, with 11 publications, or 4.2%.

Geographic Distribution

Most contributed countries are shown in Figure 5 below.

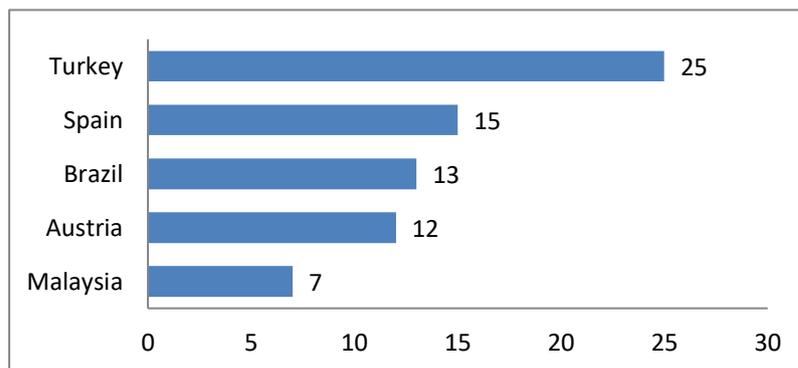


Figure 5. Geographic Distribution

The nations that contribute the most are shown in Figure 5, where there are at least 7 and up to 25 publications. With 25 documents, Turkey is the largest contributor, followed by Spain (15 publications), Brazil (11 publications), Australia (12 publications) and Malaysia (7 publications).

Most Cited Documents

Top nine most cited Documents on GeoGebra research in mathematics learning are shown below.

Tabel 1. Top 9 Most Cited Documents

No	Document Title	Authors	Year	Source	Cited By
1	Automated Theorem Proving in GeoGebra: Current Achievements	Botana, F., Hohenwarter, M., Janičić, P., (...), Recio, T., Weitzhofer, S.	2015	Journal of Automated Reasoning 55(1), pp. 39-59	68
2	Efficiency of learning environment using GeoGebra when calculus contents are in collaborative groups	Takači, D., Stankov, G., Milanovic, I.	2015	Computers and Education 82, pp. 421-431	52
3	Investigating the use of the Khan Academy and mathematics software with a flipped classroom approach in mathematics teaching	Zengin, Y.	2017	Educational Technology and Society 20(2), pp. 89-100	43
4	Conceptual Understanding of Definite Integral with GeoGebra	Tatar, E., Zengin, Y.	2016	Computers in the Schools 33(2), pp. 120-132	29
5	Examining the effects of Geogebra applets on mathematics learning using interactive mathematics textbook	Radović, S., Radojičić, M., Veljković, K., Marić, M.	2020	Interactive Learning Environments 28(1), pp. 32-49	25
6	ICT integration in mathematics initial teacher training and its impact on visualization: the case of GeoGebra	Dockendorff, M., Solar, H.	2018	International Journal of Mathematical Education in Science and Technology 49(1), pp. 66-84	25
7	Interactive maths with GeoGebra	Velichová, D.	2011	International Journal of Emerging Technologies in Learning 6, pp. 31-35	23
8	Application in augmented reality for learning mathematical functions: A study for the development of spatial intelligence in secondary students	Del Cerro Velázquez, F., Méndez, G.M.	2021	Mathematics 9(4),369, pp. 1-19	22
9	Decolonizing technological pedagogical content knowledge of first year mathematics students	Khoza, S.B., Biyela, A.T.	2020	Education and Information Technologies 25(4), pp. 2665-2679	22

Citation Trends

Table 2 illustrates the trend of quotations pertaining to GeoGebra research in mathematics instruction.

Tabel 2. Citation Analysis of Publications

Year	T (%)	NCP	TC	C/P	C/CP	h	g
2023	8	3	4	0.50	1.33	1	1
2022	22	9	38	1.73	4.22	4	5
2021	26	20	79	3.04	3.95	5	7
2020	11	10	92	8.36	9.20	5	9
2019	17	10	60	3.54	6.00	5	7
2018	11	8	71	6.45	8.87	4	8
2017	10	9	101	10.10	11.22	6	10

Year	T (%)	NCP	TC	C/P	C/CP	h	g
2016	6	4	54	9.00	13.50	4	6
2015	10	9	180	18.00	20.00	6	10
2014	2	1	13	6.50	13.00	1	2
2013	10	9	57	5.70	6.33	5	7
2012	2	2	33	16.50	16.50	2	2
2011	2	2	29	14.50	14.50	2	2
2010	2	2	25	12.50	12.50	2	2

Notes. TP=total of publication, NCP=number of cited publication, TC=total citations, C/P=average citations per publication, C/CP=average citations per cited pblication, h=h-index, g=g-index

As can be seen from Table 2, 2021 has the greatest ncp value when compared to other years, with a value of 20. Then, with 180 citations, publications in 2015 received more citations than any prior year. Even though the number of publications in 2021 was higher than the previous year, namely 26 publications (79 citations), in 2020 the impact of research was greater, namely 92 citations. The highest h-index and g-index values were in publications in 2015 and 2017, namely h-index = 6 and g-index = 10. So it can be said that 2015 and 2017 also had a big impact on this research. A total of 10 publications in 2015 have received a total of 180 citations, meaning that these publications have been cited 18 times each. A total of 101 citations were made to 10 publications in 2017, which equals to 10 citations per publication.

Research Focus

This analysis used the Vos Viewer application. To identify the research focus for GeoGebra research in mathematics learning, a keyword analysis was conducted. In searching for a research focus, the researcher divides it into three parts. The first part is a research focus on 2010–2015. The second part is a research focus on 2016–2020. The last part is a research focus on 2021–2023. The researcher set a threshold of at least two publications that contained the same keywords.

2010-2015

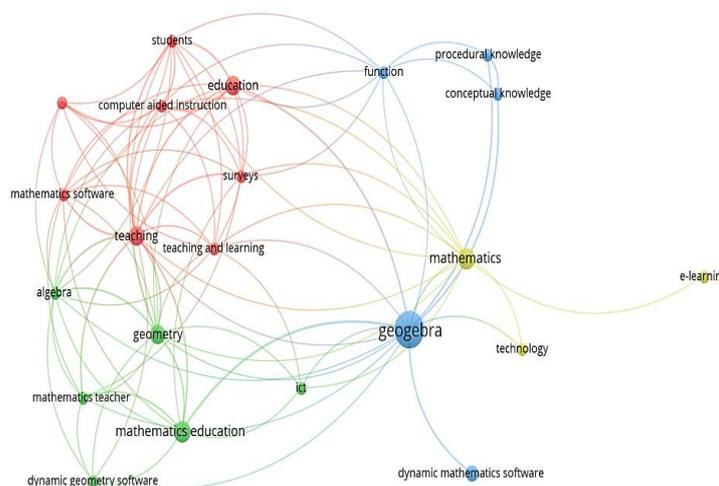


Figure 6. Research Focus 2010-2015

The clusters in Figure 6 demonstrate the focus of the research from 2010 to 2015. Several colors are evident in these clusters. A research cluster pertaining to GeoGebra research in mathematics learning is indicated by this color. Red, green, blue, and yellow are the four clusters.

This means that the research focus is divided into 4 parts, namely 1) The first cluster (in red), when viewed from the size of the circle in this first cluster, the keywords that have the largest diameter are the keywords education, and mathematics software besides keyword teaching; 2) The second cluster (in green) the keywords geometry and mathematics teacher are the largest circle in the cluster besides keyword mathematics education; 3) The third cluster (in blue), the keywords that are the focus of the dynamic mathematics software, conceptual knowledge, and procedural knowledge besides keyword GeoGebra; 4) The fourth cluster (in yellow), e-learning and technology besides keyword mathematics.

2016-2020

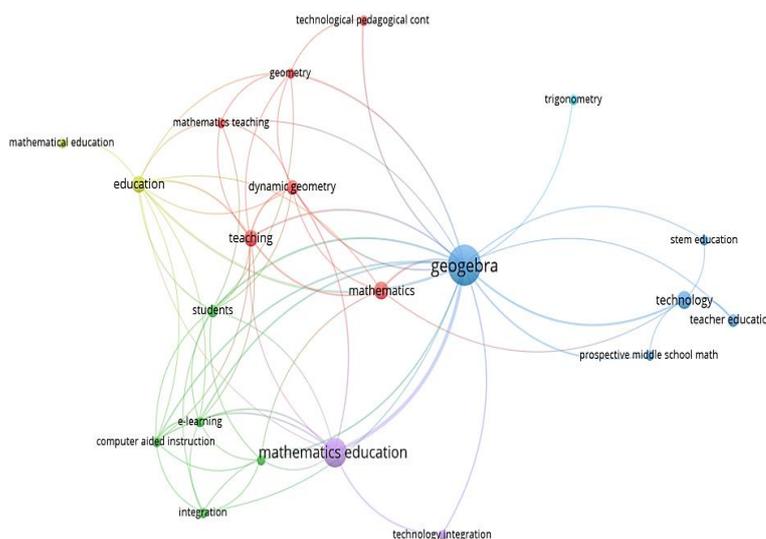


Figure 7. Research Focus 2016-2020

The clusters in figure 7 demonstrate the focus of the research from 2016 to 2020. Several colors are evident in these clusters. There are five clusters, namely red, green, blue, yellow, and purple. This means that the research focus is divided into 5 parts, namely 1) the first cluster (in red), when viewed from the size of the circle in this first cluster, the keywords that have the largest diameter are the keywords teaching and dynamic geometry besides mathematics; 2) the second cluster (in green) the keywords e-learning and integration are the largest circle in the cluster besides keyword students; 3) the third cluster (in blue), the keywords that are the focus of the technology and teacher education besides keyword GeoGebra; 4) the fourth cluster (in yellow), mathematical education and education. 5) the fifth cluster (in purple), mathematics education and technology integration.

2021-2023

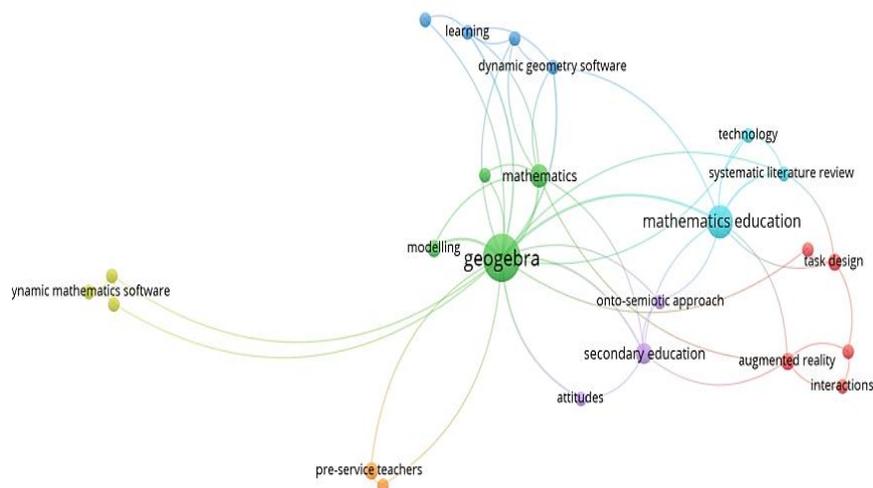


Figure 8. Research Focus 2021-2023

The focus of the research 2021-2023 can be seen from the clusters shown, in Figure 8 above, it can be seen that there are several different colors. There are seven clusters, namely red, green, dark blue, light blue, yellow, orange and purple. This means that the research focus is divided into 7 parts, namely 1) The first cluster (in red), when viewed from the size of the circle in this first cluster, the keywords that have the largest diameter are the keywords task design, augmented reality and interaction; 2) The second cluster (in green) the keywords modeling and mathematics are the largest circle in the cluster besides keyword Geogebra; 3) The third cluster (in dark blue), the keywords that are the focus of the dynamic geometry software and learning; 4) The fourth cluster (light blue), technology and systematic literature review besides mathematics education; 5) The fifth cluster (yellow), mathematical reasoning and dynamic mathematics software; 6) The sixth cluster (orange), pre-service teacher; 7) The seventh cluster (purple), onto-semiotic approach and attitudes besides keyword secondary education.

Research focuses in 2010–2015, 2016–2020, and 2021–2023 can be considered for future research. It can be seen that in the 2010–2015 and 2016–2020 ranges, the research focus was almost the same, or in other words, there were no significant differences in keywords. However, in the 2021–2023 range, the research focus will be renewed. Many new keywords have emerged. Examples of onto-semiotic approaches, attitudes, task design, augmented reality, etc. These new keywords can be considered for future research related to GeoGebra in mathematics learning.

Research Focus in 2010-2023

Specifically looking for a research focus from 2010–2023, the researcher sets a minimum threshold of three publications containing the same keywords. This is done because 2010–2023 has a very long year span, so many keywords will appear. Thus, the keywords that appear here are keywords that are in at least three publications.

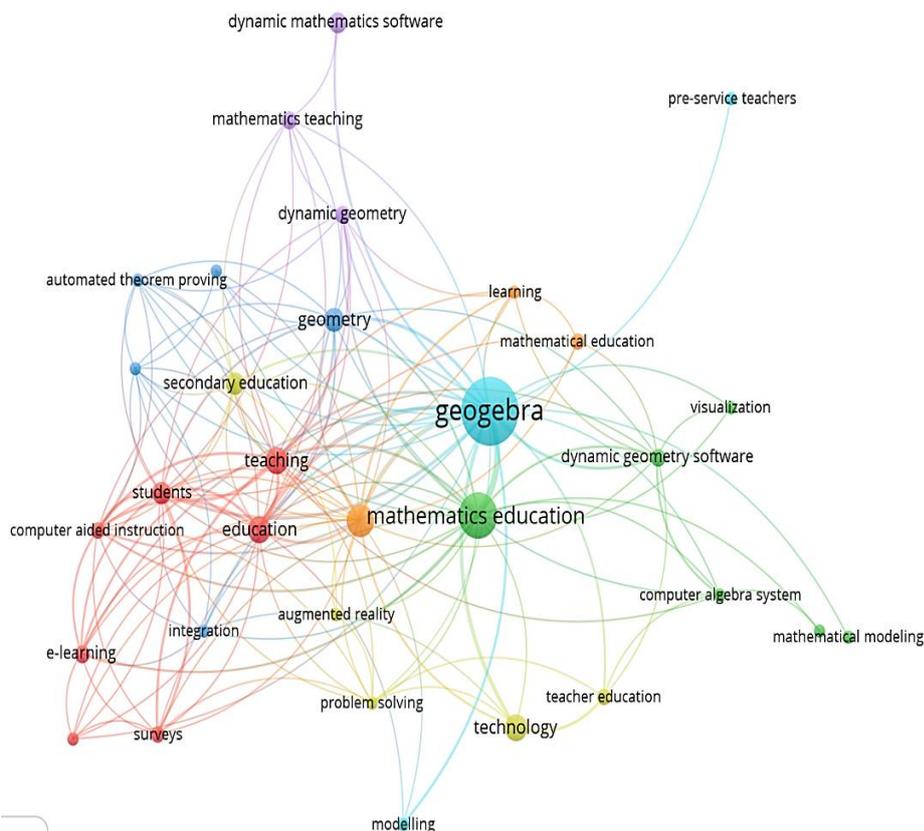


Figure 9. Research Focus 2010-2023

The following is a research focus related to GeoGebra research in mathematics learning. Keywords with a large circle diameter indicate that research with these keywords has been carried out the most. To look for updates, pay attention to keywords that don't yet have a relationship line. This is a research gap that can be used as a consideration for new research. An example in this case is research using the GeoGebra keyword associated with augmented reality and mathematical modeling.

CONCLUSION

The study's findings indicate that there is an annual increase and decrease in publications pertaining to GeoGebra in mathematics education. More publications from 2015 than from any other year have been cited. The nation with the most sway in this area is Turkey. Johannes Kepler University Lins (Austria) contributed the most to GeoGebra research in mathematics learning with eight documents. The most productive journal in research about GeoGebra in mathematics learning, is International Journal of Mathematical Education in Science and Technology with 15 documents. Most subject areas are in the social sciences, with a total of 114 publications. Research focuses in 2010–2015, 2016–2020, and 2021–2023 can be considered for future research. It can be seen that in the 2010–2015 and 2016–2020 ranges, the research focus was almost the same, or in other words, there were no significant differences in keywords. However, in the 2021–2023 range, the research focus will be renewed. Many new keywords have emerged. Many new keywords have emerged. Examples of onto-semiotic approaches, attitudes, task design, augmented reality, etc. These new keywords can be considered for future research related to GeoGebra in mathematics

learning. These novel themes suggest a fresh direction in exploring GeoGebra's impact on education. Future research could benefit from investigating these new keywords to understand their implications and contributions to the community. Analyzing the research impact of these evolving themes would enhance the relevance and significance of studies examining GeoGebra's role in enhancing mathematics education.

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