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Geogebra Research Focus in Learning Mathematics from 2007 to 2022: A Bibliometric Review Geogebra Research Focus in Learning Mathematics

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Abstract*— Geogebra is software designed for teaching and learning, whose main goal is to make math concepts clearer and easier to understand for students. This study aims to capture the landscape of previous research that is relevant to Geogebra in mathematics learning from 2007 to 2022 using bibliometric analysis. The data taken from the Scopus database was refined so that it became 91 publications. The United States, South Africa and Turkey are the most influential countries and have high cooperation with other countries in this field. The focus of this research are: 1) development of Geogebra learning media especially for junior high schools and senior high schools; 2) conceptual understanding, motivation and student learning outcomes at the university level; 3) training for teachers in conducting learning using Geogebra; 4) materials in learning mathematics such as geometry, calculus, and algebra to attract students' interest. The results of this study can be used as a reference for future researchers who wish to examine this theme in order to understand the research focus and set a path for further research.

Keywords- geogebra, mathematics learning, bibliometrics, vosviewer.

I. INTRODUCTION

Education is essential for enhancing the caliber of human resources. [1]–[3]. Mathematics is one of the most essential areas of science in education [4]–[6]. According to [7] learning mathematics has goals that support national education goals. In the process of learning mathematics, a learning media is needed [8].

Learning media is a tool in the learning process which is a vessel for conveying a message in the form of subject matter from the teacher to students [9]. One of the learning media that supports the process of learning mathematics is Geogebra [10], [11]. According to [12] Geogebra is a software program designed for teaching and learning, whose main goal is to make math concepts clearer and easier to understand for students. Meanwhile according to [13] Geogebra is a software program designed for teaching and learning, whose main goal is to make math concepts clearer and easier to understand for students. Meanwhile according to.

Research trends related to Geogebra in Education are continuously increasing. This is in line with what was stated by [14] that the number of publications tends to increase from year to year regarding Geogebra research in learning. Not only in learning in general, research related to Geogebra in learning mathematics also shows an increase every year. According to [15] geogebra research in mathematics learning in recent years has increased from 2016 to 2019. This increase in the number of publications has given rise to a large amount of academic literature.

In collecting existing knowledge, various methods of literature review can be used [16]. In a systematic literature review on previous studies the evidence reported can be summarized in a comprehensive manner [17]. Researchers can manually analyze the contents of the literature with qualitative techniques following existing research questions [18]. According to [19] include A small proportion of previous studies is a form of systematic literature review. Meanwhile according to [16] A meta-analysis differs from a systematic literature review because the empirical evidence available on previous studies is summed up in a quantitative manner. According to [20]–[29] meta analysis is a statistical method used to combine the results of different studies on the same theme or topic and can resolve conflicts between studies. The drawback of meta-analysis is that sources of bias are not controlled by the method but depend on the design and availability of covariate data in the original study [30]. The literature included in the meta-analysis tends to be less diverse [31].

Bibliometrics is a statistical method in analyzing publications [32]–[35]. Meanwhile according to [36] Bibliometrics is the basis for determining the most popular publications in a particular field. Next [35] said that bibliometrics is a research method that has very complete information by combining science, mathematics and statistics in analyzing knowledge quantitatively. Over the years, bibliometrics has developed and become a general tool for analyzing and mapping concepts and published knowledge in many fields [37], [38]. According to [16] Bibliometric

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analysis is not much different from meta-analysis in that most of the literature can be included in the review process. Conducting a bibliometric review will be especially useful for researchers in identifying research gaps and research focus [39]. So researchers seek to conduct research related to bibliometric analysis in looking at the research landscape from previous research on Geogebra in mathematics learning from 2007 to 2022.

Previous research related to Geogebra research in learning mathematics is like research conducted by [40] regarding the use of Geogebra in learning mathematics, where the results of this study indicate that the use of Geogebra can improve students' mathematical communication skills if these students have adequate initial mathematical abilities. Further research conducted by [41] related to Geogebra in mathematics learning from 2010 to 2020 from the WoS database that most of the research was conducted in high schools, and the main focus was geometry and analysis. Most of the research also discussed student learning performance. Research conducted by [42] regarding a systematic review on Geogebra research in mathematics learning, the results of the study indicate that the Geogebra software has become a determining factor in the development of mathematical competence, with an emphasis on mathematical understanding, geometric reasoning and problem solving. From the previous research above, most of them used the database from WoS, and in analyzing they did not use bibliometric analysis. For this reason, researchers conducted research related to Geogebra in learning mathematics from 2007 to 2022 with the Scopus database.

The purpose of this research was to find out the description of the research on Geogebra in learning mathematics from 2007 to 2022. The research questions discussed in this study are as follows:

1) How are the current research publication trends related to Geogebra in mathematics learning?
2) What are the research citation trends related to Geogebra in mathematics learning?
3) How is the distribution of journal ranking mapping from publications related to Geogebra in mathematics learning?
4) How is the distribution of publication mapping and relations between countries in research related to Geogebra in learning mathematics?
5) What is the focus of Geogebra's research in learning mathematics

II. METHOD

In looking for data sources related to "Geogebra in learning mathematics", researchers used the Scopus database because of its very broad interdisciplinary coverage. There are several steps in perfecting the data that has been collected as shown in Figure 1. The first is identification, then followed by screening, eligibility and finally the inclusion step [43].

The second step, screening is carried out in selecting publications in the language and type of documents required. The language that must suit the needs of researchers is English because it is the international language most used in communication in scientific work. The types of documents needed in this research are only articles and books that will be considered. After the screening process was carried out, as many as 43 publications were omitted or removed from the data because they did not meet the criteria so that only 161 publications remained.

The third step, as many as 161 publications will be assessed for eligibility. Titles and abstracts will be manually assessed by researchers to identify which publications meet the inclusion criteria, namely research that includes Geogebra in mathematics learning. This means that only publications that meet the criteria are included in the analysis related to research discussion. At the end of this stage, 70 publications were deleted because they had not involved Geogebra in learning mathematics. At the end of this third phase, 91 publications remained. The purpose of this research is to look at the trend and research landscape related to Geogebra in mathematics learning, for that all publications, namely as many as 91 publications, are included to ensure the objectivity of the interpretation results. This data was retrieved on 15 December 2022 during the inclusion stage.

The trend of publications related to Geogebra in learning mathematics is carried out by descriptive analysis taken from the Scopus database with bibliometric analysis. The number of publications and a linear line of publication trends each year from 2007 to 2022 will be displayed in a graph using Microsoft excel software.

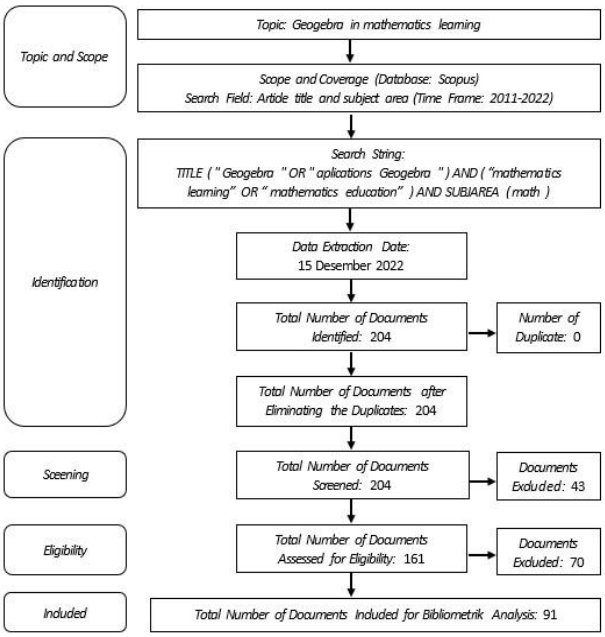

Figure 1. Data collection process

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III. DATA ANALYSIS METHODS

Trends in citations of publications related to Geogebra in mathematics learning separated by year. The average publication citations were also calculated using Microsoft Excel software. As for finding the h-index and g-index of the publication, the researcher uses Harzing's Publish or Perish software.

In displaying journal rankings based on quartile values, researchers use Microsoft Excel software to display journal ranking diagrams. Data that has been obtained from the Scopus database of 92 journals will be grouped based on (Q1), (Q2), (Q3), and (Q4). This shows the articles that have been made by researchers have been published in the journal rankings above.

In displaying the distribution of publications by country, researchers also use Microsoft Excel software to display a world map with the distribution of publications in various countries. As with the citation trend, to find the h-index and g-index of publications, researchers also use Harzing's Publish or Perish software. VOSviewer software is used to produce network visualizations that show the relationship between countries.

Analysis of events with keywords related to Geogebra in mathematics learning was carried out to determine the research focus. The data to be analyzed is taken from the Scopus database which must be processed first. The research focus can be determined from shared keywords visualized by the VOSviewer Software.

IV. RESEARCH RESULTS

The number of publications obtained at the inclusion stage was 91 selected publications from 2007 to 2010. The data sources are taken from articles with 97.80% then book chapters with 2.19%.

Publication Trends

Distribution of publications from 2007 to 2022 as shown in Figure 2 below. The highest number of publications occurred in 2021, namely 22 articles were published in that year if presented in 2021 (24.18%), then in 2017 (12.08%).

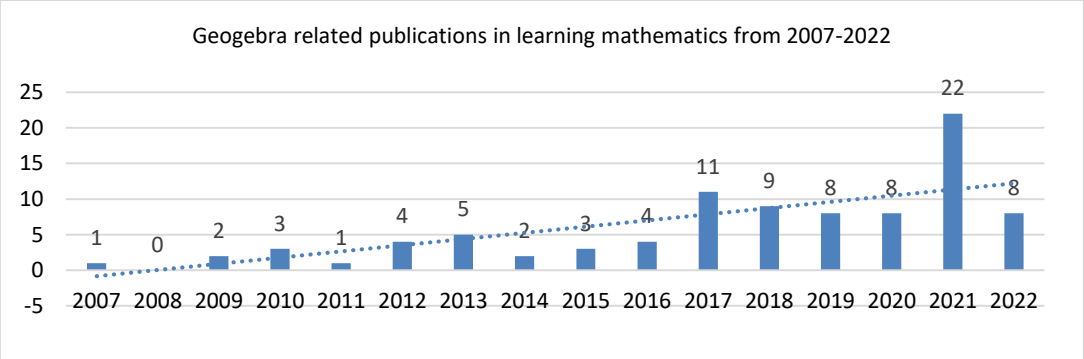

Figure 2. Number of Publications from 2007 to 2022

The increase occurred from 2020 to 2021, namely an increase of 175%. This means that there has been an increase of almost three times from the previous number of publications. Judging from the linear line or the publication trend, it shows that publications are increasing every year. The lowest number of publications was in 2008 without any publications.

Citation Trends

The trend of quotations from 2007 to 2022 related to Geogebra in learning mathematics as shown in table 1 is as follows.

Table 1: Citation Analysis of Publications

Year	TP(%)	NCP	TC	C/P	C/CP	h	g
2022	8(8,79%)	4	6	0,75	1,50	2	2
2021	22(24,18%)	10	38	1,73	3,80	4	5
2020	8(8,79%)	6	72	9,00	12,00	5	6
2019	8(8,79%)	6	43	5,38	7,17	4	6
2018	9(9,89%)	7	63	7,00	9,00	4	7
2017	11(12,09%)	10	87	7,91	8,70	6	9
2016	4(4,40%)	2	9	2,25	4,50	2	3
2015	3(3,30%)	2	5	1,67	2,50	2	2
2014	2(2,20%)	1	5	2,50	5,00	1	1

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Year	TP(%)	NCP	TC	C/P	C/CP	h	g
2013	5(5,49%)	5	36	7,20	7,20	3	5
2012	4(4,40%)	5	99	24,75	19,80	4	4
2011	1(1,10%)	1	2	2,00	2,00	1	1
2010	3(3,30%)	3	107	35,67	35,67	3	3
2009	2(2,20%)	2	91	45,50	45,50	2	2
2008	0(0,00%)	-	-	-	-	-	-
2007	1(1,10%)	1	72	72,00	72,00	1	1

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

Table 1 above shows that the number of publications cited (NCP) in 2021 and 2017 is the highest (NCP = 10). The highest total citations were in 2010 with 107 citations, then followed by 2012 with 99 citations, even though the highest number of publications was in 2021, but several publications in the previous year had a very large research impact, such as from 2011 which was only 2 quotes rose sharply to 99 citations.

Judging from the g-index and h-index which are calculated annually, it shows that in 2017 the g-index and h-index reached the highest with an h-index of 6 and a g-index of 9. This means that in 2017 it had the highest impact on Geogebra in learning mathematics, where in 2017 11 articles have been published with 87 citations and at least 10 publications have been cited at least 9 times each.

Journal Rating Mapping Distribution

Based on the Scopus database, Quartile (Q) values are obtained from a journal. The 91 publications obtained were grouped based on the Q value as follows.

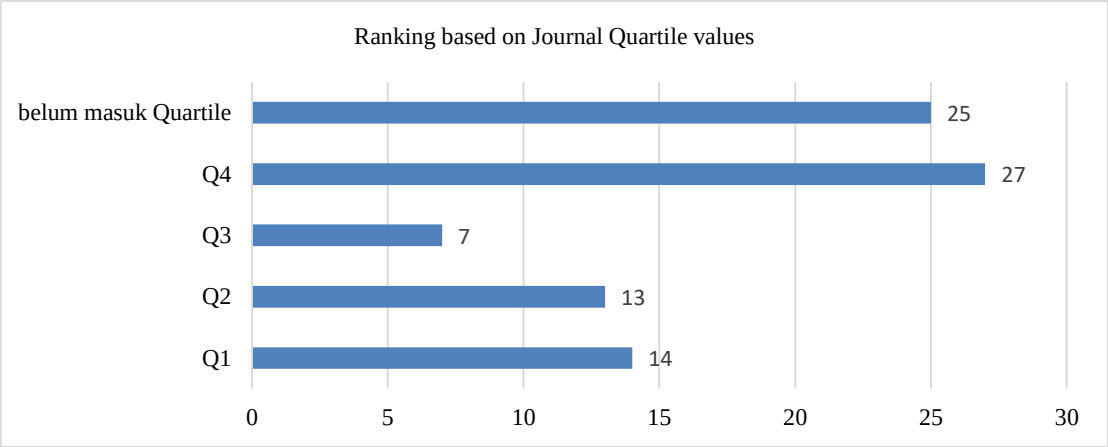

Figure 3. Ranking based on Journal Quartile values

From the picture above, the most articles related to Geogebra in mathematics learning are written in journals with Q4 in the journal ranking system, namely 27 articles. This is because journals that have a Q1 value are more selective in selecting articles, making it more difficult in terms of publication. This means that the writing of articles related to this field must be further improved so that more and more articles will be published in journals that have a Q4 value and above. Q1 with 14 articles, Q2 with 13 articles, and Q3 with 7 articles.

Geographic Distribution of Publications

Countries are identified based on the country of origin of the journal. Figure 4 shows the geographical distribution of publications, based on this figure, a total of 19 countries, countries with more than one publication can be seen in table 2. From table 2 there are seven countries.

Figure 4 shows that America and England are the most influential in this field. The United States has published 23 articles, while the United Kingdom has published 38 articles. If these two countries combined, it has more than 65 percent of the total publications.

The Americas, Asia, and Europe have published articles, while the continents of Australia and Africa have not published articles related to geogebra in mathematics learning in Scopus indexed journals. The Americas and Europe are the continents that publish the most articles, because countries on the continents of America and Europe, namely the United States and England, have the number of publications, respectively 22 and 38.

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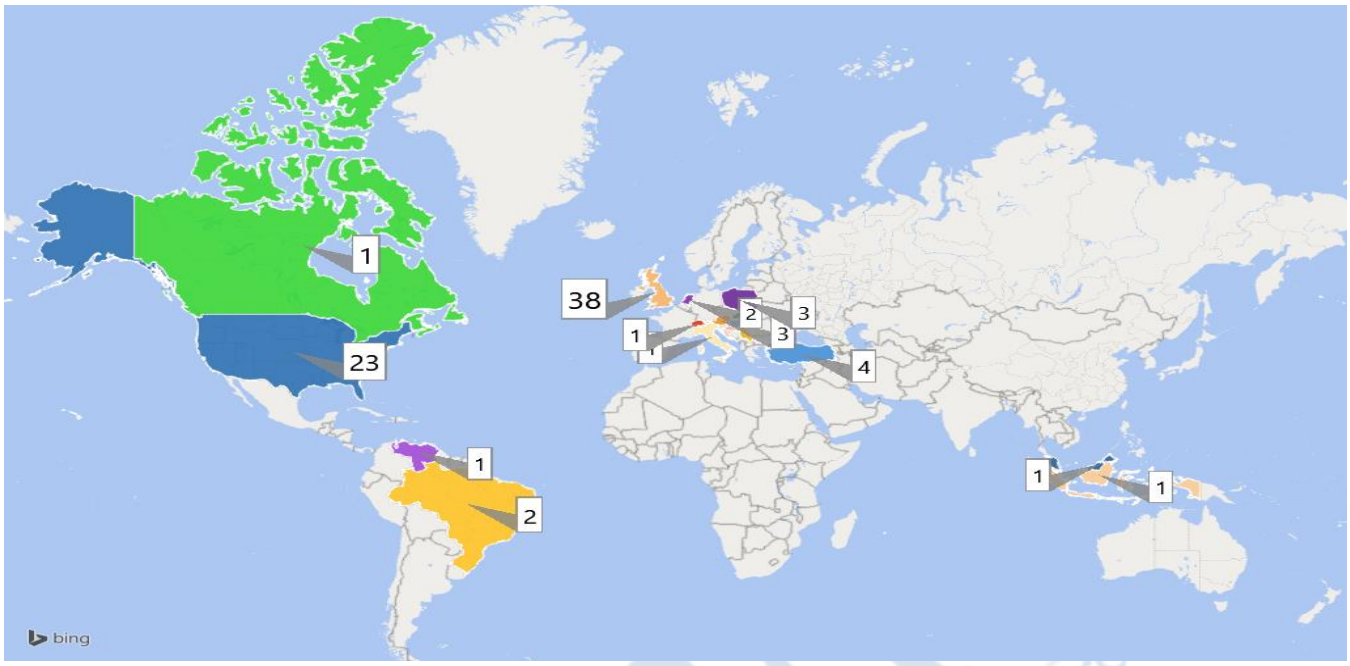

Figure 4. Geographic Distribution of Publications

Countries with more than one publication are listed in table 2, there are seven countries that have more than one publication. The United Kingdom has a number of publications of 43 percent of the total, with a total of 327 citations which is the highest number of citations than any other country. Affected countries are calculated from the g-index and h-index values. England is the country with the largest research impact with g-index =17; h-index =9. In second place is the United States with g-index = 12; h-index = 5. Next is Turkey with g-index = 4; h-index =4.

Table 2: Countries with more than one article published

Country	TP(%)	NCP	TC	C/P	C/CP	h	g
Inggris	38(41,75%)	27	327	8,60	12,11	9	17
Amerika serikat	23(25,27%)	17	158	6,86	9,29	5	12
Turki	4(4,39%)	4	68	17	17	4	4
Polandia	3(3,29%)	2	4	1,33	2	2	2
Austria	3(3,29%)	3	31	10,3	10,3	2	3
German	2(2,19%)	2	15	7,5	7,5	1	2
Brazil	2(2,19%)	-	-	-	-	-	-

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

Global Collaboration Patterns

In Figure 5, shows the pattern of global collaboration based on the author's country of origin which is displayed by network visualization with the VOSviewer software, the researcher sets a threshold, namely countries with a minimum of 2 documents that will be displayed, from 30 countries it shrinks to 15 countries after the threshold is set, from 15 these countries, the United States, Turkey and South Africa have the most relations with other countries, this can be seen by the many links spread from the three countries with 13 links each, but not all countries are directly related to the three countries, For example, there is a British country that is not related or has no links with the United States, then there is a South Korean country that has no links either with Turkey or with South Africa.

South Korea is a country that has the least relations with other countries, where it only has cooperation with three other countries. Of the 15 countries, there are 4 clusters. With the largest cluster that is with a red circle. The other clusters are given a color (blue, yellow, and green).

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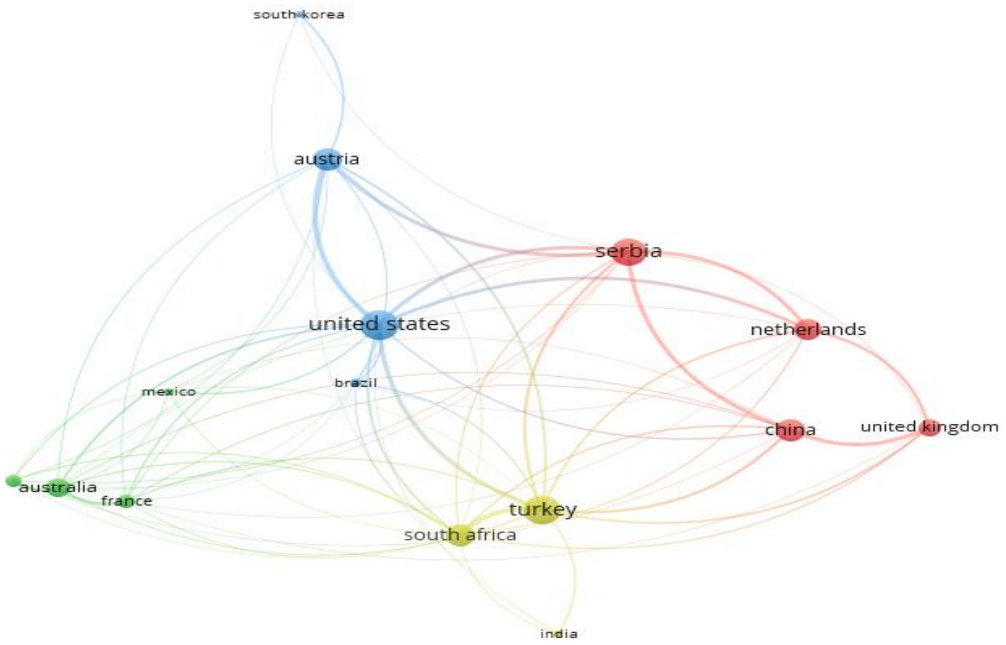

Figure 5. Pattern of Global Collaboration

Research focus

Analysis of occurrences with keywords was carried out to determine the research focus on Geogebra in learning mathematics. Researchers set a threshold that is at least 2 publications that contain the same keywords. From these results, the 90 keywords were reduced to 38 keywords.

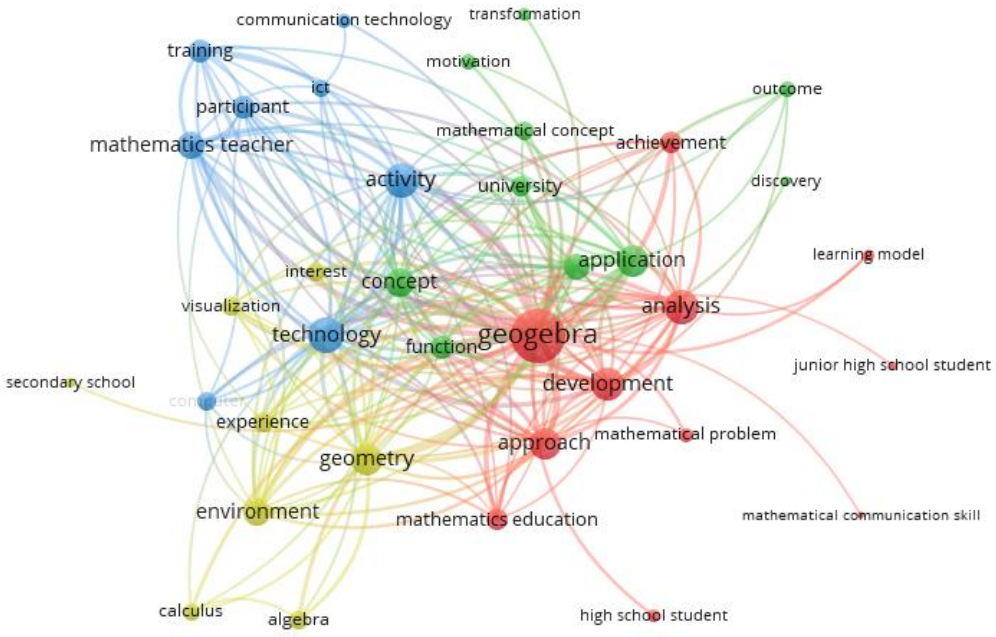

Figure 6. Keyword Co-occurrence (Occurrence Threshold ≥ 2)

The results of the network visualization in Figure 6 show that there are 4 clusters with 38 items regarding Geogebra in Mathematics Learning, namely, 1) Cluster 1 (red in color) is the largest cluster consisting of 11 items (achievement, analysis, approach, development, Geogebra, high school student, junior high school student, learning model, mathematical communication skills, mathematical problems and mathematics education) the keywords Geogebra and development have the largest circle among the other cluster 1, meaning that these keywords reflect the focus of joint

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research with students in junior high schools and high schools ; 2) cluster 2 (in green) consists of 10 items with the keywords mathematical concept, understanding and university having a larger circle than the others, meaning that conceptual understanding at the university level is the focus of research together with motivation and learning outcomes; 3) cluster 3 (dark blue) consists of 9 items where the circles on the keywords teacher mathematics, training, technology and activity are the largest in the cluster, meaning teacher training on the use of ICT and technology is the focus of research; 4) cluster 4 (yellow) consists of 8 items with the keywords geometry, calculus, algebra has the largest circle among cluster 4, meaning that the material geometry, calculus and algebra along with the students' learning interests reflects the research focus.

V. DISCUSSION

This study aims to display the research landscape related to Geogebra in mathematics learning from 2007 to 2022. The following will discuss research questions..

How are current research publication trends related to Geogebra in mathematics learning?

The trend of publications related to Geogebra in learning mathematics from 2007 to 2022 shows that publications have increased from 2020 to 2021, the highest number of publications occurred in 2021 where there were 22 publications published. This is in accordance with what was conveyed by [14] that the number of publications tends to increase from year to year related to Geogebra research in learning.

The number of publications in 2021 is 22, but only 10 have been cited at least once, meaning that there are 12 publications that have not been cited at all. More than half of the total number of journals that have never been cited. The h-index and g-index values in 2017 were the largest compared to other years. However, when viewed from the number of citations, 2010 was the year with the highest number of citations, namely 107 citations. The number of documents in 2010 was 3 documents. The 3 documents can be seen in table 3 as follows.

Table 3. Articles published in 2010

No	*Author (year)*	*Title*	*Sources*	*Citation*
1	Saha, 2010 [44]	Pemanfaatan Adobe Flash Cs6 Berbasis Problem Based Learning Pada Materi Fungsi Komposisi Dan Fungsi Inver	*Procedia - Social and Behavioral Sciences*	86
2	Reis 2010 [45]	*Computer supported mathematics with Geogebra*	*Procedia - Social and Behavioral Sciences*	18
3	Mussoi 2010 [46]	*Geogebra and eXe Learning: applicability in the teaching of Physics and Mathematics*	*International Conference on Society and Information Technologies-ICSI*	3

The publication in 2010 that has the highest number of citations is research conducted by [44] regarding the Effect of Geogebra on Mathematics Learning Achievement: Enlightening the Learning of Coordinate Geometry with a total of 86 citations. While in second place the research conducted by [45] which discusses computer-supported mathematics with Geogebra with a total of 18 citations.

What are the research citation trends related to Geogebra in mathematics learning?

The publication that has the highest number of citations is in 2010 which is shown in table 3 with a total of 86 citations. Even though in 2010 there were only 3 published articles. Research conducted by [44] with the title "The Effects of Geogebra on Mathematics Achievement: Enlightening Coordinate Geometry Learning" has been cited 86 times, meaning that the number of citations in one article has exceeded 80% of the number of citations in that year. Article written by [44] widely cited because the article presents the effect of Geogebra in learning mathematics, especially on mathematics learning achievement where the results of the research show that the use of Geogebra improves student performance in learning Coordinate Geometry.

Article written by [45] in 2010 it became the publication with the second most citations with 18 citations. This article has been widely cited because it attempts to conceptualize the subject of mathematics using a new software, Geogebra, in providing permanent learning for students. The subject of integers has been taught by different methods in two homogeneous classes. One of the classes is taught using traditional teaching techniques, while the other is taught using Geogebra. To evaluate how much they understand the subject, a test is administered immediately after the lesson. Two weeks later, a new test was administered to see how much the subjects remembered. After that, by comparing the results of the two exams, the contribution and benefits of Geogebra in learning Mathematics were analyzed. Where the results of this study indicate that with Geogebra, students are more involved in the process and more sensory organs are appealed to, so that the success achieved is higher. Judging from the g-index and h-index which are calculated annually,

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it shows that in 2010, even though it had the highest number of citations, the g-index and h-index values were 3 each..

How is the distribution of journal ranking mapping from publications related to Geogebra in mathematics learning?

The ranking of the journal that has the highest number of articles is based on the Q value from the Scopus database, where there are still many articles that have not been published in Q1-Q4, as many as 25 articles that are still published in journals that have not been indexed by Scopus. While the second rank is Q4 with a total of 27 articles, then the number of articles in the journal that has the highest quartile value or Q1 is as many as 14 articles. The journals entered in Q1 are as follows.

Table 4. List of Q1 journals related to Geogebra in learning mathematics.

Nama jurnal	Number of articles
Education and Information Technologies	3
Interactive Learning Environments	2
Computer Applications in Engineering Education	1
Computers in the Schools	1
Education Inquiry	2
Heliyon	1
International Journal of Emerging Technologies in Learning	1
Journal of Ambient Intelligence and Humanized Computing	1
Journal of Computer Assisted Learning	1
Malaysian Journal of Learning and Instruction	1
Research in Mathematics Education	1

Education and Information Technologies is the entry journal (Q1) with the highest number of articles. The journal comes from the United States with "Kluwer Academic" as publisher. This means that the journals above can be used as a reference for researchers who research Geogebra in learning mathematics can publish their articles in the journals in table 4 above.

How is the distribution of publication mapping and relations between countries in research related to Geogebra in mathematics learning?

The two countries with the highest number of publications related to Geogebra in mathematics learning when viewed from the country of origin of the journals are the United States and England. These two countries are spread across two continents, namely the American continent and the European continent. The country with the top order based on the number of publications is the United Kingdom. Total publications from the UK are 40% of the total. The total publications from these two countries, namely the United States and England, reached 65% of the total

Relations or collaboration between countries are also dominated by the United States, with two other countries namely South Africa and Turkey with each having a total of 13 links, where almost all countries that publish articles related to Geogebra in mathematics learning collaborate with the United States, Africa South and Turkey, while the UK is also the country with the highest level of collaboration with 6 total links.

What is the focus of Geogebra's research in learning mathematics?

Researchers identified a research focus related to Geogebra in learning mathematics based on the clusters shown. The focus of the research is divided into four, namely, 1) development of Geogebra media which focuses on the junior and senior high school levels; 2) students' understanding of concepts at the university level along with motivation and learning outcomes; 3) training for teachers on the use of technology and ICT; 4) geometry, calculus and algebra along with students' learning interests

The main research focus is the development of Geogebra learning media as well as junior and senior high school education levels, such as the research conducted by [47] about the development of Geogebra learning media for junior high school students. The results of this study indicate that learning media with a realistic approach assisted by Geogebra meet the effective criteria of mastery of spatial abilities reaching 87.5% and the learning time is not much different from the usual learning time. Media development for the senior high school level is also a research focus, this is in line with research conducted by [48] who examines the bibliometric analysis of the use of Geogebra for problem solving. The results of this study indicate that the most influential document related to Geogebra is research that discusses Geogebra in high schools. As well as the appearance of the development keyword, it is one of the keywords that is often used in Geogebra research.

The second research focus is on students' conceptual understanding at the university level along with motivation and learning outcomes. Learning with Geogebra learning media at the university level gives students the opportunity to make connections between symbolic, visual, and numerical representations. Students must learn new techniques and must be able to model and evaluate situations that are challenging, interesting, and real [49]. As for the third research focus, namely regarding training for teachers on the use of technology and ICT. The importance of training teachers on the use of technology, especially in learning to

use Geogebra. This is in line with what was stated by [50] the importance of using Geogebra remains in teacher's daily practice, for this reason Dockendorff suggests that further research can examine students' attitudes towards using Geogebra in mathematics classes, curricular mathematics content aimed at Geogebra, and its impact on learning and how to increase its use as an exploratory tool.

The fourth or final research focus is geometry, calculus and algebra along with students' learning interests. Geometry, calculus and algebra are materials in learning mathematics. According to [51] dynamic geometry, algebra and calculus can be combined and exist in the Geogebra software system. For this reason, further research is needed regarding these three materials in mathematics learning which can attract student learning interest. The four research focuses above are the focus of current research related to Geogebra in learning mathematics.

VI. CONCLUSION

The trend of publications related to Geogebra in learning mathematics has increased in 2021. The highest number of citations was in 2010 with 107 citations. Of the 91 journals published from 2007 to 2022, 14 of them have been included in the Q1 journal ranking. Articles about Geogebra seen from the geographic distribution based on a wide country have a high impact on learning mathematics. The focus of research in this field is as follows: 1) development of Geogebra learning media; 2) conceptual understanding, motivation and student learning outcomes; 3) training for teachers in conducting learning using Geogebra; 4) materials in learning mathematics such as geometry, calculus, and algebra to attract students' interest. The four research focuses are gaps and research landscapes that encourage future researchers to conduct relevant research in Geogebra in learning mathematics.

VII. SUGGESTION

The limitations of this research are; 1) the data analyzed comes from the Scopus database, so there are many other databases that can be used such as Wos and others; 2) this research only discusses Geogebra in learning mathematics, so there are many other fields of education that can be further investigated; 3) data in this study taken on December 15, 2022 cannot reflect research after that time, so there may be slight differences

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