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The Impact of GeoGebra in Analytic Algebra: A Bibliometric Review

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Abstract: GeoGebra is a software that is often used in mathematics learning. GeoGebra is an electronic program that contains a set of tools that equip students with mathematical skills. This research aims to look at research trends related to algebra learning that integrates GeoGebra. This research is literature review research, there are 95 publications collected from the Scopus database which are then analyzed using the bibliometric analysis method assisted by the Vos viewer application. Data taken from the Scopus database was refined in 4 stages, namely identification, filtering, eligibility, and inclusion, resulting in 95 publications. The research results show that Spain and Austria are the most influential countries and have high cooperation with other countries in this field. The focus of research related to GeoGebra on algebra material is, 1) geometry and students; 2) GeoGebra and algebra; 3) elementary geometry and computational theory; 4) dynamic geometry and computer algebra. The new themes in this research are symbolic computation, quantifier elimination and real quantifier elimination. This research not only enriches the scientific literature in the fields of GeoGebra and algebra but also provides practical guidance for educators and researchers to improve mathematics teaching and learning methods in the future.

Keywords: GeoGebra, Algebra, Mathematics education

Introduction

Technological developments have had a significant impact on the field of education by making understanding easier and increasing excitement in the learning process (Jan, 2017; Kristanto et al., 2016; Murtikusuma et al., 2019; Sriyanto & Kaniadewi, 2019). Therefore, the use of technology can improve the quality of education through learning media pembelajaran (Joshua et al., 2016; Oktavianingtyas et al., 2018; Rohaeti et al., 2019).

The use of learning media aims to convey something abstract to be realistic to improve student understanding and student learning outcomes (Rohaeti et al., 2019). Improving understanding and learning outcomes using technology depends on students' literacy in information and communication technology (ICT) (Fatahillah et al., 2020). According to Garba (2014), ICT literacy includes five components, namely: accessing, managing, integrating, evaluating, and creating. Therefore, in today's education system, ICT literacy needs to be developed because it affects student learning outcomes (Markauskaite, 2006; Solar et al., 2013; Tadesse et al., 2018; Thammasaeng et al., 2016). Current mathematics learning has integrated ICT learning media. Many applications can be used in learning mathematics, such as spss, maple, math lab, GeoGebra, Microsoft mathematics, and

others (Ekawati, 2016). By integrating mathematics learning through ICT, it makes it easier for students to understand concepts to solve mathematical problems (Sivakova et al., 2017). Research by Toma et al. (2023) revealed that with the use of ICT in learning there is a significant difference to improve performance, develop participatory skills, and have the ability to provide positive results to students.

GeoGebra is one of the software that is often used in learning mathematics Al-Alawi (2017) defines GeoGebra as an electronic programm that contains a set of tools that equip students with mathematical skills. This software is very useful for teachers and students, but it cannot replace the role of the teacher. The main topics in mathematics that can use GeoGebra software consist of Algebra, Geometry, and Maths (Al-Noaimi, 2016). In this GeoGebra software, the system used can be classified into 2 systems, namely: Computer Algebra System (CAS), because it contains algebraic and conceptual processes involving equations and coordinates; the second is Dynamic Geometry Software System (DGS), because it contains geometry concepts such as points, lines, 2D shapes, and 3D objects. This makes students understand information about the relationship between concepts.

Meanwhile, Al-Balawi (2013) stated that GeoGebra is a tool that can help students acquire mathematical skills easily and interestingly. GeoGebra is designed to enable students to gain a deep understanding of mathematical theories and facts through the exploration and practice of these concepts. Using GeoGebra in learning mathematics creates a new dimension in the process of acquiring a mathematical concept, especially the topics of algebra and geometry.

One of the most important topics in learning mathematics is algebra. This is in line with the opinion of Wang (2015) who states that algebra has been recognized as an important part of mathematics learning as well as a lot of emphasis in to overcome the difficulties and challenges in learning algebra. Algebra is a complex material and is dominated by abstract concepts (Hodgen et al., 2015; Hodgen et al., 2018). Abstract concepts and the variety of symbols used in learning concepts, procedures, and problem-solving strategies (Cousins-Cooper et al., 2017; Ferretti et al., 2018). make it difficult for teachers to find the best method to teach algebra and students have difficulty learning algebra (Cousins-Cooper et al., 2017; Garzón & Bautista, 2018). Nevertheless, teachers can still improve student learning by implementing evidence-based learning strategies and teachers are expected to have a deep understanding of algebra knowledge content and forms of intervention in algebra learning (Cousins-Cooper et al., 2017; Lee et al., 2020).. The form of intervention can be done by using GeoGebra software in learning algebra. Research by Latifi et al. (2021) revealed that using GeoGebra in learning can improve students' conceptual abilities in differential equation material.

The theme of research on learning algebra using GeoGebra software is interesting to study. However, we consider it necessary to conduct a bibliometric analysis on this theme. Bibliometric analysis is conducted to update research information on mathematics education (Julius et al., 2021). Using bibliometric analyze makes it possible to analyse data from citation indices to see the reputation and influence of specific research papers, authors, and publications (Julius et al., 2021). In addition, bibliometric analysis also allows one to quantitatively evaluate major journal titles and keywords and stream publications in an academic context in a more coordinated way. As for other relevant data relating to the academic community, one can visualize the interaction between authors from different universities, institutions, and countries.

According to Cancino et al. (2017), the existence of bibliometric studies as a literature greatly contributes to the art of introducing many fields of interest. For example, certain phenomena can be assessed and investigated in various fields ranging from the field of social sciences (Aria et al., 2020; Uribe-toril et al., 2020) to science and technology (Andreo-Martínez et al., 2020; Jiang et al., 2020), engineering (Haleem et al., 2020; Marzi et al., 2020), education (Gil-Doménech et al., 2020; Shen & Ho, 2020), etc. Recently, Wei et al. (2023) have conducted a bibliometric analysis by comparing the current research status, research hotspots, and development trends of teachers' attention in mathematics education. In mathematics education research, the literature search method systematically uses bibliometric tools combined with a more qualitative approach.

In general, this study aims to look at research trends related to algebra learning that integrates GeoGebra. Therefore, in this study, a bibliometric analysis will be conducted (Hawkins DT, 2001; Linnenluecke et al., 2020) to systematically analyze existing works that focus on learning algebra that integrates GeoGebra.To systematically analyse existing works that focus on learning algebra using GeoGebra; by sorting out research advances, drawing a visual knowledge map and relevant literature, and visually revealing learning algebra using GeoGebra that pays attention to research and developmental trends in this file. Do not underline words for emphasis. Use italics instead. Both numbered lists and bulleted lists can be used if necessary. Before submitting your manuscript, please ensure that every in-text citation has a corresponding reference in the reference list. Conversely, ensure that every entry in the reference list has a corresponding in-text citation.

Method

This research uses bibliometric methods. This technique incorporates a systematic analysis of published articles, including citations, to assess the impact of these articles (Maditati et al., 2018). The bibliometric analysis used in this study is descriptive bibliometrics that describes the characteristics or features of a literature. Bibliometric analysis techniques are divided into 2 categories, namely work analysis and mapping (Donthu et al., 2021)

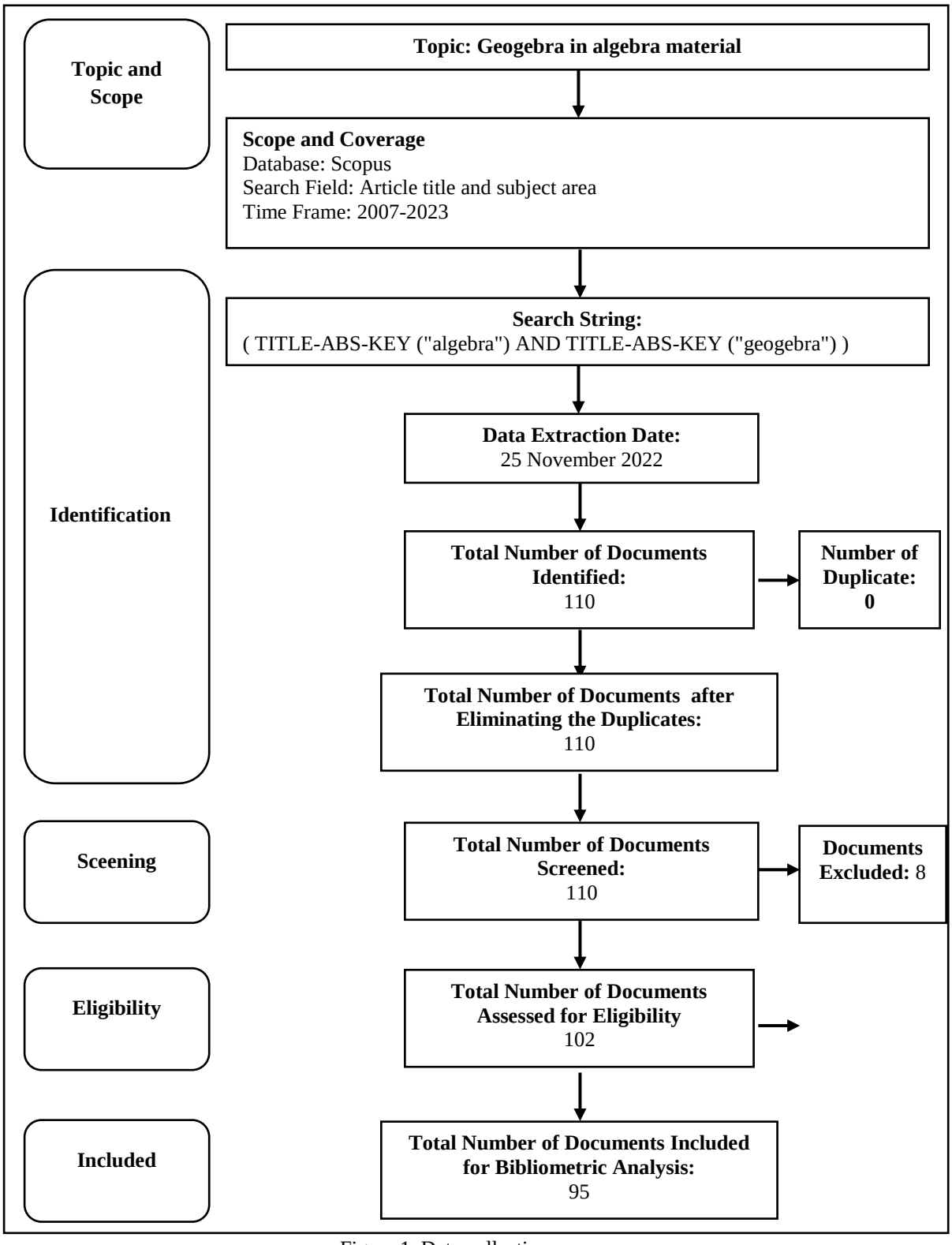

Figure 1. Data collection process

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In searching for data sources related to "GeoGebra on algebra material", researchers use the Scopus database because of its very broad interdisciplinary coverage. There are several steps in refining the data that has been collected as shown in Figure 1. First is identification, then proceed with the screening step, eligibility, and finally the inclusion step (Moher et al., 2009).

The first step, identifying relevant publications using a search string and removing the same or duplicate publications. The topic and scope is "GeoGebra on algebra material" There are 110 publications and no duplicates were obtained. The second step, screening is done by selecting publications on the type of document required. That is, to find the publications needed to be more effective, an advanced search is carried out by limiting the type of document, namely only documents of the article and conference paper type that will be included in the next stage. At this stage, 102 publications were obtained and will be continued at the next stage.

In the third step, 102 publications will be assessed for eligibility. Titles and abstracts will be manually assessed by researchers to identify which publications match the inclusion criteria, namely research that includes GeoGebra in algebra material. This means that only publications that fit the criteria are included in the analysis related to the discussion of the research. The language that must match the needs of the researcher is English because it is the most widely used international language in communication in scientific work. At the end of this stage, 7 publications were deleted because they used a language other than English. At the end of this third stage, 95 publications remained. The purpose of this study is to see the trends and landscape of research related to GeoGebra in algebra material, for all publications, namely 95 publications, are included in the inclusion stage to ensure the objectivity of the interpretation results. This data was collected on 4 November 2023 during the inclusion stage.

Data Analysis Method

Publication trends related to GeoGebra in algebra material are carried out by descriptive analysis taken from the Scopus database with bibliometric. The number of publications and the linear trend of publications each year from 2007 to 2023 will be displayed in a graph using Microsoft Excel software. Publication citation trends related to GeoGebra in algebra material are separated by year. The average citation per publication is also calculated using Microsoft Excel software. As for finding the h-index and g-index of the publication, researchers used Harzing's Publish or Perish software.

In displaying the journals with the highest number of articles as well as seeing the quartile value, researchers use Microsoft Excel software to display journal ranking diagrams. In displaying the distribution of publications by country, researchers also use Microsoft Excel software. Analysis of events along with keywords related to GeoGebra in algebra material is carried out to determine the focus of the research. The data to be analyzed is taken from the Scopus database which must first be processed. The research focus can be determined from the shared keywords visualized by VOS viewer Software.

Results and Discussion

The number of publications obtained at the inclusion stage is 95 selected publications in the last decade, starting from 2007 to 2023. The data source was taken from articles with 47.4% then conference papers with 52.6%.

Publication Trend

The distribution of publications is shown in Figure 2 from 2007 to 2023. The highest number of publications occurred in 2021, namely as many as 18 articles published in that year if it is presented in 2021 (19%), then in 2022 (14%).

A significant increase in the number of publications per year related to GeoGebra on algebra material occurred from 2020 to 2021, namely a 6-fold increase. Judging from the linear line or publication trend, it shows that publications are increasing every year. In 2008 there were no articles published. The next lowest number of publications is 1 publication per year which occurred in 2007, 2009, and 2010. This means that the development of publications related to GeoGebra in algebra material has increased since 2011. Although initially, from 2007 to 2010, there was at most only one publication per year, this situation has changed dramatically in the last few years. In recent years, there has been a drastic surge in the number of publications related to GeoGebra and

algebra. The fact that the number of publications in 2021 increased 6 times compared to 2020 shows the increasing interest and focus of researchers in exploring and publishing information related to GeoGebra in the context of algebra. In 2008, no publications related to GeoGebra and algebra were found, but since then, the trend has been positive. The use of GeoGebra tools in teaching and learning algebra has become an increasingly important research subject for academics and researchers. This change reflects the growing interest in the application of technology in learning mathematics, especially in the context of algebra, and shows that GeoGebra has become a very relevant and valuable tool in the world of mathematics education.

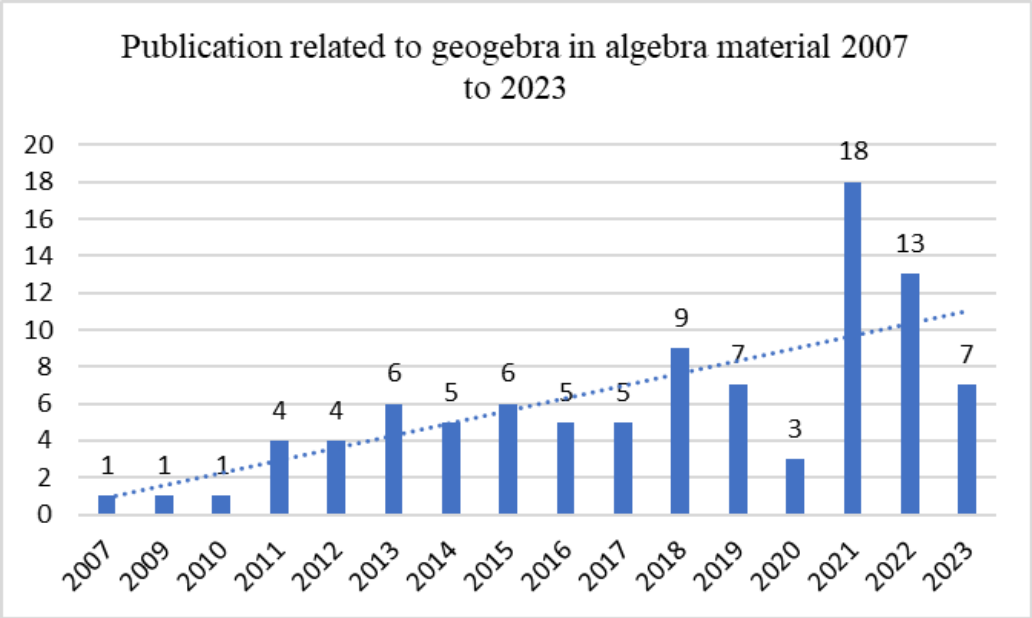

Figure 2. Publications from 2007 to 2023

These developments have made a significant contribution to the understanding and methods of teaching algebra. With the number of publications increasing every year, it can be assumed that mathematics researchers and educators are increasingly recognising the value and potential of GeoGebra in helping students understand algebraic concepts more interactively and visually. In addition, this positive trend also reflects a response to technological developments and the need for more innovative and dynamic approaches to learning. GeoGebra provides opportunities for practical mathematical exploration, allowing students to better visualize algebraic concepts, which in turn can improve their understanding (Suryawan & Permana, 2020; Yanti et al., 2019). In the academic context, the increasing number of publications also shows that the scientific community recognizes the value of GeoGebra-related research in the context of algebra. Findings and innovations in the use of GeoGebra in algebra learning have the potential to penetrate the formal education curriculum and help refine mathematics teaching methods at various levels of education. Therefore, seeing these positive developments, it can be expected that research and publications related to GeoGebra and algebra will continue to grow in the future. This will not only benefit the teaching and learning of mathematics, but will also open the door for discoveries in the world of mathematics education that can shape a generation of students who are more skilled and knowledgeable in the field of algebra.

Quote Trends

Citation trends over the past decade related to GeoGebra in algebra as shown in Table 1 from 2007 to 2023. The Table 1 shows that the number of publications related to GeoGebra on algebra material cited (NCP) in 2021 is the highest with (NCP = 9). The highest total citation was in 2015 with 139 total citations, although the highest number of publications was in 2021, several publications in the previous year had a very large research impact, such as from 2014 when only 18 citations rose sharply to 139 citations. Looking at the h-index calculated per year shows that in 2015 the h-index reached its highest with an h-index of 5. This means that this data also provides important insights into the dynamics of research and citations. While the number of publications in 2015 may not be as many as in 2021, the impact on the scientific community is huge. This emphasizes the importance of not only looking at the number of publications but also measuring the influence and acceptance of research by academics and other researchers.

Table 1. Citation analysis of publications

Year	TP(%)	NCP	TC	C/P	*h*	*g*
2023	7	1	1	0,14	1	1
2022	13	8	14	1,08	2	3
2021	18	9	45	2,50	4	6
2020	3	1	1	1	1	1
2019	7	5	23	3,29	3	4
2018	9	8	25	2,78	3	4
2017	5	5	14	2,80	2	3
2016	5	4	38	7,60	3	5
2015	6	6	139	23,17	5	6
2014	5	5	18	2,40	2	4
2013	6	5	29	4,83	2	5
2012	4	2	10	2,50	2	3
2011	4	2	9	2,25	2	3
2010	1	1	2	2	1	1
2009	1	1	30	30	1	1
2008	-	-	-	-	-	-
2007	1	1	74	74	1	1

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

The importance of 2015 in the history of GeoGebra and algebra research can also be interpreted as a turning point in the development of knowledge in the field. Research in that year may have introduced new concepts, innovative methods, or revolutionary applications of GeoGebra in learning algebra. As such, these publications have paved the way for further research, inspiring other researchers to explore the new ideas introduced that year. One of the most cited publications in 2015 was the research conducted by Botana et al. (2015). Botana et al. (2015) said the use of GeoGebra's performance, which is equipped with automatic deduction tools, is already very promising as many complex theorems can be proved in less than 1 second. Therefore, we believe that many new and exciting ways of using GeoGebra in the classroom are coming soon.

Analyzing this data also provides direction for future research. While 2021 showed an increase in the number of publications, it is important to understand the factors that made 2015 such an influential year. Further research could be conducted to identify the characteristics of research in 2015 that made it so successful, as well as to understand how the findings are still relevant and applicable in the current context of mathematics education. In conclusion, this data provides a deeper look into the complexities and dynamics of scientific research. Progress in GeoGebra and algebra is not only reflected in the numbers but also in the tangible impact that these studies have on the scientific community and mathematics education. Therefore, understanding the context and true value of scientific publications can provide valuable clues for future research directions and help enrich our understanding of GeoGebra's role in improving algebra learning.

Journal Ranking Mapping Distribution

Based on the Scopus database, the Quartile (Q) value of a journal is obtained. From the 95 publications obtained, grouping is then carried out based on the number of articles in each journal.

Table 2. Sources with the highest number of articles related to GeoGebra

Source	*Number of Articles*	*Quartile*
Lecture Notes in Computer Science	15	Q3
Mathematics in Computer Science	9	Q3
Journal of Physics: Conference Series	5	Q4
CEUR Workshop Proceedings	5	Not included
Proceedings of the Asian Technology Conference in Mathematics	4	Not included

From the table above, articles related to GeoGebra on algebraic material are mostly written in Q3 and Q4 journals in the journal ranking system, from the top 5 journals 2 journals do not yet have a quartile value. This is because journals that have a Q value are more selective in choosing articles so it is more difficult in terms of

publication. This means that the writing of articles related to this field must be further improved so that more articles will be published in journals that have a Q value. The focus of writing articles related to GeoGebra in algebra material should be strengthened in journals ranked above quartile Q3 and Q4. Although writing articles in these journals may be more difficult due to high selectivity, this is what makes it a very valuable target. Researchers and academics need to strive to improve the quality of research, methodology, and contribution to knowledge in every article they write. In addition, researchers need to keep abreast of the latest developments in GeoGebra and algebra. By understanding research trends and the needs of the scientific community, article writing can be directed to topics that are more relevant and significant. Strengthening cooperation between researchers and institutions can also be an effective strategy to produce higher-quality research that is relevant to the needs of quality journals.

In this context, increasing the number of articles published in journals with high quartile scores can also support the development of academic and institutional reputations. Quality articles published in prestigious journals will contribute greatly to improving the image of researchers, institutions, and even countries in the global scenario. Therefore, authors, researchers, and educational institutions need to work together to produce high-quality research and submit it to journals with high quartile scores. This will not only increase the visibility and impact of the research, but will also advance the field of GeoGebra and algebra as a whole. With an awareness of the importance of publication in quality journals, the scientific community can spur themselves to achieve higher standards of excellence in their research, thereby enriching the scientific literature and supporting the future development of mathematics education.

Geographical Distribution of the Publications

Countries are identified based on the country of origin of the journal. Figure 3 shows the geographical distribution of publications, based on which, there are 10 countries with the highest number of publications. Figure 3 shows that Spain and Austria are the most influential in this field. Spain has published 29 articles, while Austria has published 27 articles. These two countries combined account for more than 55 percent of the total publications. This means that the geographical distribution of publications reveals the significant influence of two countries, Spain and Austria, in the field of research related to GeoGebra and algebra. With a total of 29 publications for Spain and 27 for Austria, both countries have made an enormous contribution to the scientific literature in this field. When the number of publications from these two countries is combined, they account for more than half, i.e. 55 percent of the total.

In other words, Spain and Austria have played a key role in the development of knowledge about the use of GeoGebra in algebraic contexts. This success may reflect the existence of active research centers, strong scientific cooperation, or innovative teaching approaches in higher education institutions in both countries. The important role of Spain and Austria highlights the importance of cross-border collaboration in scientific research. International collaboration can enrich perspectives, broaden the scope of research, and produce more holistic solutions to complex challenges in GeoGebra and algebra.

In addition, these results provide an overview of the global diversity in approaches and research into GeoGebra in the context of algebra, which may inspire researchers from other countries to engage in similar studies or collaborate with researchers from Spain and Austria. In the context of mathematics education, understanding the dominant role of Spain and Austria also provides opportunities for other countries to learn from their experiences and approaches to the use of GeoGebra. By engaging various perspectives and best practices from different countries, the scientific community can continue to enrich learning methods and improve students' understanding of algebra, creating a positive impact on global mathematics learning.

It is important to recognize that GeoGebra was first developed on Austria by Hohenwarter (2001). Therefore, it is not surprising that Austria has a significant impact in GeoGebra-related research, given the country's origins in the development of this software. Austria's strong contribution to GeoGebra-related publications reflects the continuity and depth of domestic research into GeoGebra applications in algebraic contexts. Thus, Austria's presence as the second country with the highest number of publications is very natural. This achievement reflects Austria's commitment to advancing mathematical knowledge, especially in the field of algebra, through the use of GeoGebra as an effective and innovative learning tool. Austria's success in GeoGebra-related publications also illustrates how the home country of educational technology development can lead and inspire research at the international level, bringing benefits to the global scientific community.

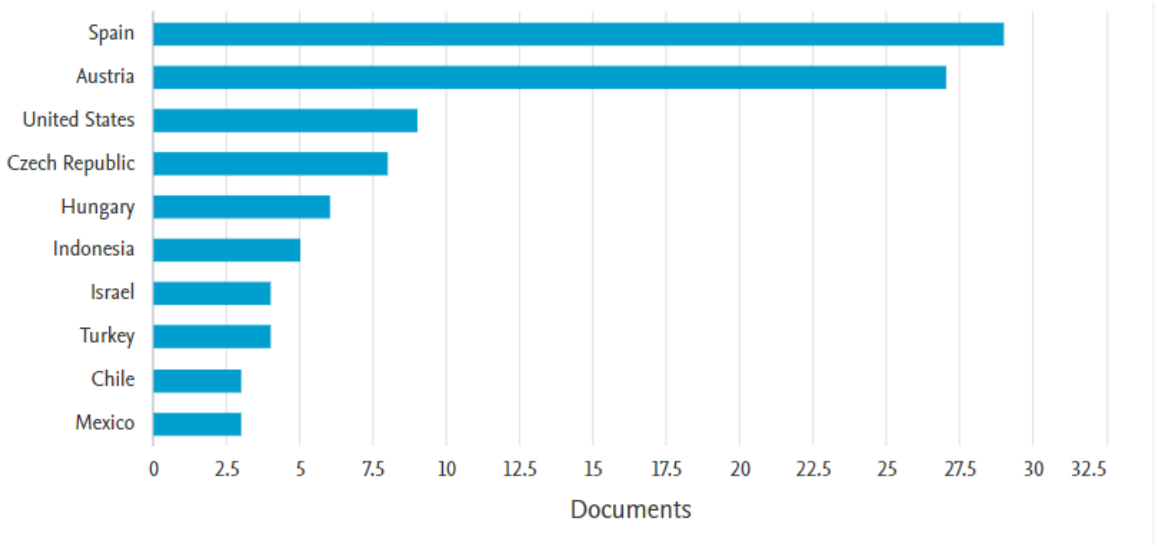

Figure 3. Geographical distribution of publications

Research Focus

Keyword co-occurrence analysis was conducted to determine the focus of research on GeoGebra on algebra material. Researchers set a threshold of at least 3 publications containing the same keywords. From these, results 529 keywords were reduced to 33 keywords.

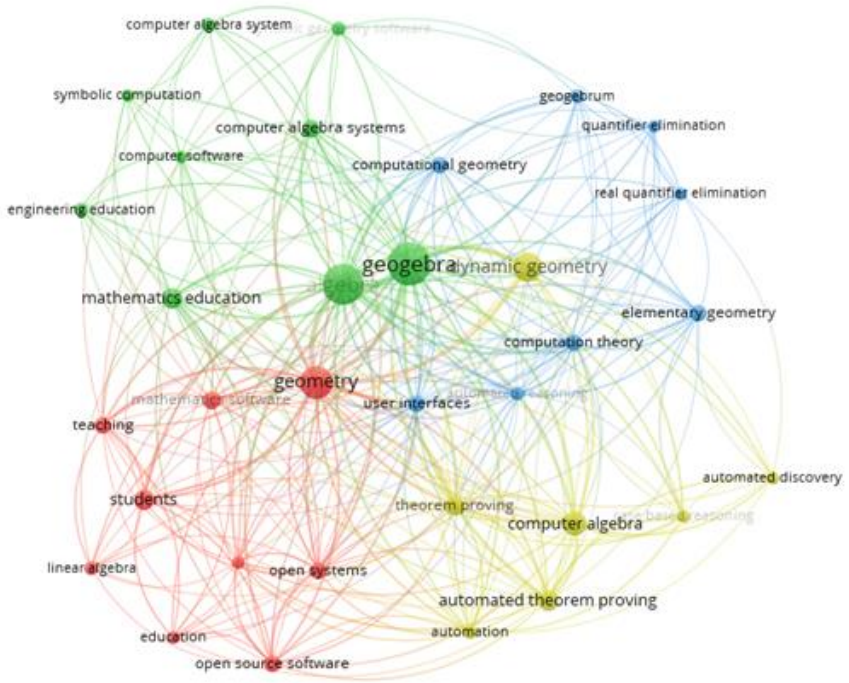

Figure 4. Keyword co-occurrence network (Occurrence Threshold ≥ 4)

The results of the network visualization in Figure 4 show that there are 4 clusters with 33 items regarding GeoGebra on algebra material, namely, 1) Cluster 1 (in red) is the largest cluster consisting of 9 items, the keywords geometry and student have the largest circle among other cluster 1, meaning that these keywords reflect the first research focus; 2) cluster 2 (in green) consists of 9 items with the keywords GeoGebra and algebra having a large circle than the others, meaning that these keywords reflect the second research focus; 3) cluster 8 (dark blue) consists of 4 items where the circle on the keywords elementary geometry and computation theory is the largest in the cluster, meaning that the keywords reflect the third research focus; 4) cluster 4 (yellow) consists of 7 items with the keywords dynamic geometry and computer algebra, meaning that the

keywords reflect the fourth research focus. This means that the results of the network visualisation in Figure 4 provide in-depth insight into four research clusters related to GeoGebra in algebra material. The first cluster, marked in red, highlights the keywords "geometry" and "student" as the main focus of research. These two keywords stand out with the largest circles, indicating that the research in this cluster mainly focuses on the use of GeoGebra in teaching geometry concepts to students. This reflects the great interest in understanding the interaction between algebra and geometry, particularly in the context of student learning.

The second cluster, represented in green, shows that the focus of the research is on the keywords "GeoGebra" and "algebra". The large circles around these two keywords indicate that the research in this cluster is more focused on the application of GeoGebra in teaching, and learning algebra. This reflects efforts to investigate how GeoGebra can be used to facilitate algebraic understanding, emphasizing the importance of technology integration in mathematics learning. The third cluster, marked in dark blue, highlights the keywords "elementary geometry" and "computation theory" as the main focus of research. The large circles on these two keywords indicate that the research in this cluster focuses on specific aspects of geometry and computation theory, exploring how GeoGebra can be applied in these contexts. This shows the diversity in the application of GeoGebra, including at the level of basic geometry and computation theory.

The fourth cluster, represented by yellow, shows that the research in this cluster focuses on the keywords "dynamic geometry" and "computer algebra". The large circles on these keywords depict research that explores the interaction between dynamic geometry and computer algebra, showing how GeoGebra is used to incorporate these concepts in mathematics learning. Taken together, the results of this visualisation provide an in-depth look at the research focus within the field of GeoGebra on algebraic materials. By highlighting different aspects of geometry, algebra and computation, these studies make a diverse and knowledge-rich contribution to the use of GeoGebra in mathematical contexts, enriching understanding and approaches to learning in this area.

Impact and implementation

The results of the study that identified various research focuses related to GeoGebra in algebra materials provide a clear picture of the impact and implementation of this technology in the context of learning mathematics. The use of GeoGebra in teaching algebra not only allows students to visualize abstract concepts more concretely and interactively but also facilitates independent exploration and problem-solving. With the integration of GeoGebra in algebra learning, students can be more actively involved in the learning process, improve their understanding of algebraic concepts, and develop critical and analytical thinking skills. In addition, the results of this study also provide an in-depth look at how GeoGebra can be implemented in the mathematics curriculum. By understanding the diverse focus of the research, educators can design more focused and relevant teaching strategies. The development of learning materials that integrate GeoGebra can help overcome the challenges of learning algebra, such as students' difficulties in understanding abstract concepts or boredom with less interactive learning.

This positive impact is not only felt by students, but also by educators and researchers. Educators can improve the quality of their teaching by utilizing GeoGebra as a dynamic and interactive tool. Researchers have the opportunity to deepen their research by focusing on specific areas that have been identified, paving the way for discoveries in the use of GeoGebra in the context of algebra. Overall, this research provides a strong foundation for strengthening GeoGebra integration in algebra learning. By utilizing these findings, educators can design more dynamic and relevant learning experiences, provide students with the ability to better understand and master algebraic concepts, and ultimately, strengthen their grounding in mathematics that will be useful in various contexts of their future lives.

Novelty of Research

In Figure 5, the novelty of GeoGebra-related research on algebra material is indicated by yellow circles, yellow circles indicate new keywords used in recent years. The keywords with the new theme are symbolic computation, quantifier elimination, and real quantifier elimination. The use of symbolic computation keywords indicates that the research involves manipulating mathematical symbols to explain algebraic concepts symbolically without regard to specific numerical values. In addition, the keyword quantifier elimination indicates the use of mathematical techniques of logic and model theory to eliminate quantified variables in mathematical formulas or statements, while real quantifier elimination emphasizes the use of these techniques in the context of real numbers. Thus, this research highlights the application of GeoGebra in simplifying complex

algebraic equations and solving mathematical problems involving real numbers with a more in-depth and complex approach.

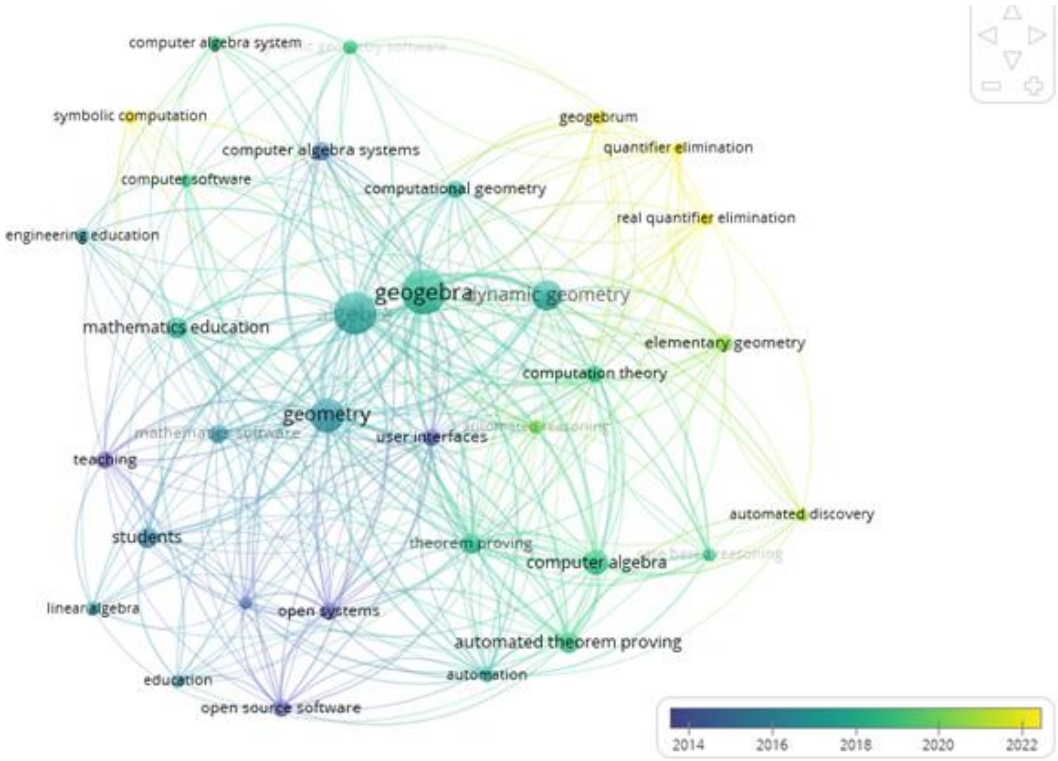

Figure 5. Overlay visualization

Conclusion and Recommendations

From the results and discussion, it can be concluded that the development of publications related to GeoGebra in algebra material has increased since 2011 and peaked in 2021 with a total of 18 publications. The geographical distribution of publications reveals the significant influence of two countries, namely Spain and Austria in the field of research related to GeoGebra and algebra. The focus of research related to GeoGebra on algebra material is, 1) geometry and students; 2) GeoGebra and algebra; 3) elementary geometry and computation theory; 4) dynamic geometry and computer algebra. New themes in this research are symbolic computation, quantifier elimination, and real quantifier elimination. The four research focuses and new themes related to GeoGebra on algebra material can be used as a reference for future researchers who want to determine the focus and theme of their research related to this field.

The use of GeoGebra in learning algebra makes a significant contribution to the development of students' mathematical knowledge. The research findings highlighted a variety of foci, ranging from the application of GeoGebra in geometry to integration with algebra and computational theory. It is this diversity that demonstrates GeoGebra's versatility and relevance in mathematics education. The positive impact of using GeoGebra is seen in students' improved understanding of algebraic concepts, which strengthens their ability to solve mathematical problems creatively and analytically. In addition, this research also underlines the importance of international collaboration and the implementation of GeoGebra in the mathematics curriculum. The integration of GeoGebra in learning not only changes the way students understand algebra but also provides opportunities for educators to design interactive and engaging learning experiences. As a result, this research not only enriches the scientific literature in the field of GeoGebra and algebra but also provides practical guidance for educators and researchers to improve teaching and learning methods of mathematics in the future.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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