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**Original Article**

# Bibliometric Analysis of Trigonometry Learning and Education

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**Abstract**
Trigonometry is a fundamental aspect of mathematics education, connecting sophisticated mathematical principles with practical applications in disciplines such as physics, engineering, and architecture. This bibliometric study examines a century of research on trigonometry education, utilizing 126 papers indexed in the Scopus database with the search phrases "trigonometry" and "learning" or "education." Data were analyzed utilizing bibliometric methods, including Bibliometrix, to illustrate trends in publication production, citation impact, and research themes. The analysis indicates a consistent annual increase of 2.93% in research production, albeit a significant portion of the literature is antiquated. Collaboration is common, averaging 2.54 co-authors per work; nevertheless, international cooperation is still restricted. Trigonometry, referenced 51 times, is a primary emphasis of the research. Research indicates that conventional pedagogical approaches impede student comprehension, whereas the integration of technology such as GeoGebra markedly improves educational results. The results underscore the necessity for creative instructional strategies and enhanced collaboration to advance trigonometry education, with forthcoming research focusing on international partnerships and efficacious teaching methodologies.

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## 1. Introduction

An essential part of mathematics education, trigonometry links sophisticated mathematical ideas with practical uses. It covers the study of triangles, the relationships between their angles and sides, and the functions of sine, cosine, and tangent—all of which are fundamental in subjects including physics, engineering, and architecture (Demitra & Dewi, 2021; Simons & Wibawa, 2021; Weber, 2008). For students, mastery of trigonometric ideas is essential since it prepares them for calculus and other higher-level mathematics, hence improving their problemsolving ability and mathematical reasoning (Asomah et al., 2023; Demitra & Dewi, 2021; Simons & Wibawa, 2021). Technology's integration into trigonometry instruction has demonstrated how well it helps students grasp and interact with the subject (Paulin, 2024). Cooperative learning and activity-based learning settings are among the effective educational tools that help to build closer links among mathematical ideas, so improving students's comprehension and retention (Asomah et al., 2023; Maphutha et al., 2023). Trigonometry thus not only improves mathematical knowledge but also provides important abilities required for success in several scientific and technical fields (Fox & DeJarnette, 2022; Malambo, 2020; Tugas, 2023).

Trigonometry's teaching and learning have changed dramatically over time from conventional techniques to more creative approaches combining technology and active learning practices. Traditionally, trigonometry was mostly taught using traditional "chalk and talk" techniques, which frequently resulted in student problems in understanding abstract concepts and making connections between trigonometric principles and real-world applications (Maphutha et al., 2023; Mosese & Ogbonnaya, 2021; Weber, 2008). Recent advancements have brought technologies like GeoGebra and tangible user interfaces that improve

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students' conceptual understanding and enable interactive learning (Naidoo & Govender, 2014; Urrutia et al., 2019). Notwithstanding these developments, trigonometry teaching still presents difficulties. Many students find it difficult to connect trigonometric ideas with other mathematical disciplines, such geometry and algebra, therefore impairing their capacity to solve problems (Baidoo, 2024; Maphutha et al., 2023). Teachers' efficacy in delivering trigonometric instruction is further hampered by their sometimes-insufficient pedagogical content knowledge (Delima, 2022; Spangenberg, 2021). Particularly during the COVID-19 epidemic, the combination of blended learning and technology has showed promise in tackling these issues; nonetheless, the requirement of continuous professional development for teachers is still very important (Baidoo, 2024; Gunadi & Rosyadi, 2022).

Improving student comprehension and performance in this challenging topic depends on an awareness of the effects of many teaching approaches, tools, and strategies on trigonometry learning. Studies show that compared to conventional teaching strategies some instructional approaches—including the use of technology like GeoGebra—much increase students's grasp of trigonometric ideas. Furthermore, creative approaches such project-based learning and cooperative learning have been demonstrated to increase student involvement and cooperation, so improving learning results (Asomah, 2023). Understanding the difficulties students have studying trigonometry—that is, with regard to algebraic transformations and mental connections—allows teachers to properly modify their lessons (Ngu & Phan, 2020, 2023). Using worked examples and analogy-based learning, for example, will enable students to more successfully negotiate challenging situations. Moreover, the combination of blended learning strategies shows promise in clearing misunderstandings and improving general trigonometry performance (Baidoo, 2024). Therefore, designing appropriate pedagogical solutions that satisfy various learning needs depends on a thorough awareness of these educational dynamics.

Several reasons, notably the necessity to solve ongoing difficulties in teaching and learning this complicated topic, drive the growing interest in evaluating the research scene of trigonometry education. Advanced mathematical ideas and many applications in disciplines such physics and engineering depend on trigonometry as a basic component (Arhin & Hokor, 2021; Jelatu et al., 2019). But pupils frequently struggle to grasp trigonometric ideas, which can impede their general mathematical growth (Arhin & Hokor, 2021; Sekgoma, 2023). Recent studies have underlined how well creative teaching strategies and technology tools including GeoGebra and dynamic online software improve students' understanding of trigonometric functions (KepceoÄŸlu & Yavuz, 2016; Mosese & Ogbonnaya, 2021; Naidoo & Govender, 2014). These resources enable interactive learning opportunities that can help close the distance between theoretical ideas and useful applications (Naidoo & Govender, 2014; Urrutia et al., 2019). Research on instructional tactics, including the use of worked examples and analogy-based learning, has also showed promise in enhancing students's problem-solving capacity in trigonometry (Ngu & Phan, 2020, 2023). Examining current research becomes increasingly important as teachers try to hone their approaches and raise student results. It makes it possible to pinpoint successful educational strategies and create focused interventions meant to solve the particular difficulties trigonometry's students encounter (Baidoo, 2024; Maphutha et al., 2023). A better knowledge of trigonometry and improved teaching approaches depend on this continuous research.

By giving a quantitative perspective of the academic output in this topic, a bibliometric analysis can greatly help to map current research trends in trigonometry education. This approach reveals the most important papers, authors, and publications in trigonometry education by using statistical methods to examine publication trends, citation statistics, and authorship networks (Aksoy et al., 2021; Watrianthos et al., 2022). Understanding how trigonometry is taught and learnt in different contexts depends on knowing how emerging themes, research gaps, and the change of educational practices over time are identified by such studies (Bayrak & Aslanci, 2022; Mokhtar Brika et al., 2021). Furthermore, bibliometric instruments such as VOSviewer and Biblioshiny help researchers to visualise complicated data, so enabling them to identify relationships between several studies and track the effect of particular approaches or teaching tools on student outcomes (Hafiar, 2023; Sampson et al., 2013). Teachers and legislators can decide on curriculum development, budget allocation, and the acceptance of creative teaching practices by methodically classifying and evaluating the literature (Ab Rahman, 2022). In the end, bibliometric analysis is a great tool for promoting cooperation among academics and practitioners, so improving the general standard of trigonometric education (Ambarita, 2024; Verma & Gustafsson, 2020). Therefore, the aim of this research is as follows: What are the publication trends related to trigonometry learning and education?;Who are the

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most influential authors, institutions, and countries contributing to the field?; What are the core research themes and future research directions?

## 2. Method

The purpose of this bibliometric study is to quantify the bibliographic pattern of scientific publications. Researchers can describe the progression of trigonometric research in education thus far using this way. Data for this study were gathered from scholarly papers with Scopus index that involved international scholars with no time constraints (Hod, 2022). The selection of the Scopus database was based on its vast coverage, comprehensive and dependable information, direct download capability, and direct processing compatibility with other bibliometric analysis tools. Because bibliometric analysis is pertinent to comprehending research trends and orientations, it was selected (Al Husaeni & Dani Nandiyanto, 2021). Utilizing search terms associated with the article's title, abstract, and keywords, data were retrieved from the Scopus database. On October 5, 2024, the following query was used to get data: "(TITLE-ABS-KEY"trigonometry" AND ("learning" OR "education" ))." It is anticipated that this data source will offer a thorough overview of the impact of trigonometric research in the field of education. Descriptive analysis and bibliometric data visualization are the methods of data analysis that are employed. Bibliometrix and other applications were used to examine the data. To observe how trends evolve over time, the distribution of publications annually and the trend of often researched themes are also examined. This method of analysis will aid in describing the general direction and style of trigonometric study.

## 3. Results and Discussion

### Results

The 100-year dataset comprises data from 126 publications from 1924 to 2024. Analysis of 175 documents shows a constant but moderate rise in research output of 2.93% per year. The average document age is 9.31 years, suggesting the research may be outdated. The dataset averages 8.731 citations per item, indicating moderate citation effect. The dataset contains 333 algorithmically generated keywords (Keywords Plus) and 560 author-assigned keywords, demonstrating the researchers' wider term selection. Only 46 of the 434 document authors wrote alone. The 48 single-authored documents show that most research is collaborative. Average coauthors per document are 2.54, showing significant collaboration, but only 8.571% engage international co-authorship, indicating low cross-border collaboration. Every 175 documents in the dataset are articles. The stable growth rate, moderate citation impact, and high collaboration tendencies indicate a solid, albeit dated, research landscape with opportunities for international collaboration.

Table 1.
*Main Information*

| Description | Results |
|---|---|
| Timespan | 1924–2024 |
| Sources (Journals, Books, etc) | 126 |
| Documents | 175 |
| Annual Growth Rate (%) | 2.93 |
| Document Average Age | 9.31 |
| Average citations per doc | 8.731 |
| References | 0 |
| Keywords Plus (ID) | 333 |
| Author's Keywords (DE) | 560 |
| Authors | 434 |
| Authors of single-authored docs | 46 |
| Single-authored docs | 48 |
| Co-Authors per Doc | 2.54 |
| International co-authorships (%) | 8.571 |

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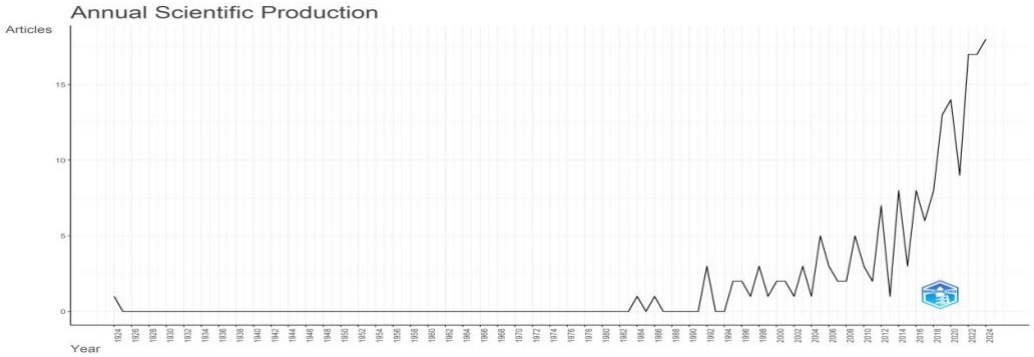
| Description | Results |
|---|---|
| Article | 175 |

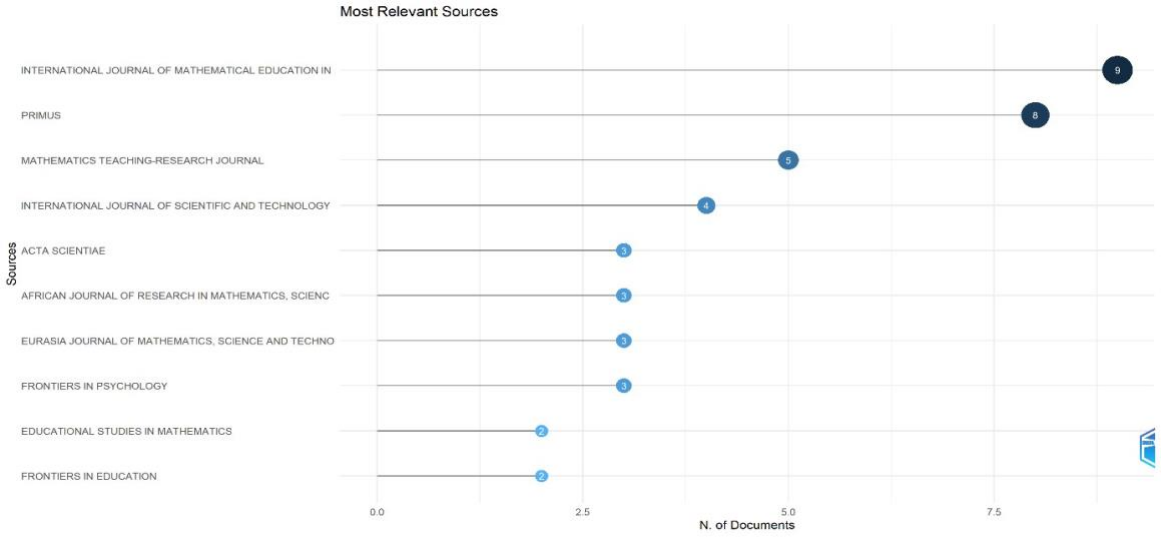
The dataset displays 1924–2024 article distributions. From 1924 until 1986, few research articles were published. In 1924, 1984, and 1986, only one paper was published, indicating almost complete idleness for decades. The 1990s saw some research growth. Three articles appeared in 1992, up somewhat. 1995, 1996, and 1998 also had two or three articles. Output was lower than in succeeding years despite this expansion. Starting in the early 2000s, article numbers increased steadily. In 2005 and 2009, 5 articles were published. Seven articles were published in 2012, continuing the moderate but steady development in research output. Since 2014, research production has increased significantly. Eight articles were published that year, followed by 13 in 2019, and 14 in 2020. 17 articles were published in 2022 and 2023, continuing the rise. 18 articles are expected in 2024, indicating the dataset's peak research activity.

Figure 1
*Annual Production*




*The International Journal of Mathematical Education in Science and Technology* has the most articles, 9. It is followed by *PRIMUS* with 8 articles and *Mathematics Teaching-Research Journal* with 5. Next with 4 articles is the *International Journal of Scientific and Technology Research. Acta Scientiae*, the *African Journal of Research in Mathematics, Science, and Technology Education*, *Eurasia Journal*, and *Frontiers in Psychology* have published three pieces apiece. Each papers, *Educational Studies in Mathematics* and *Frontiers in Education*, submitted two pieces. This distribution shows which journals publish most research, mostly in mathematics and scientific education publications.

Figure 2
*Most Relevant Sources*



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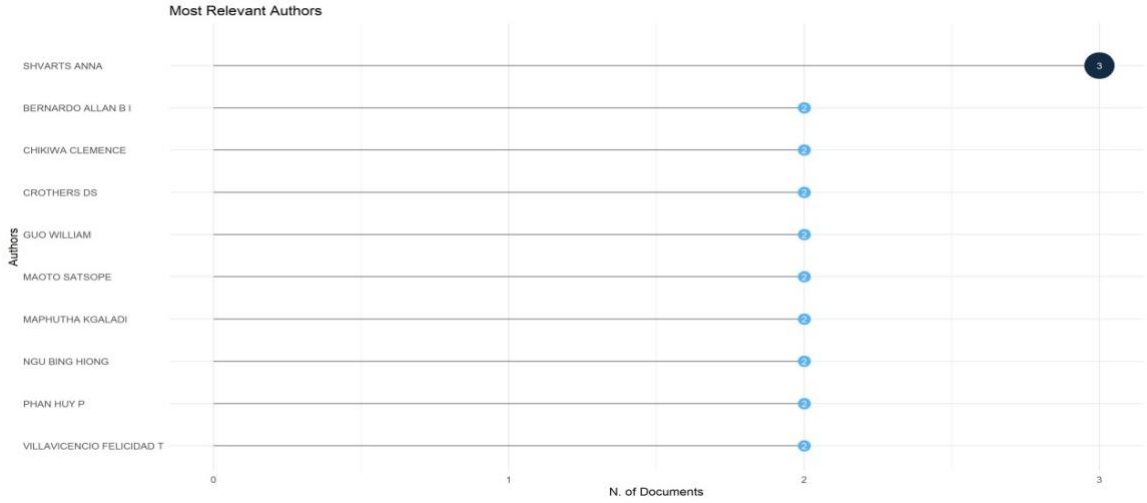
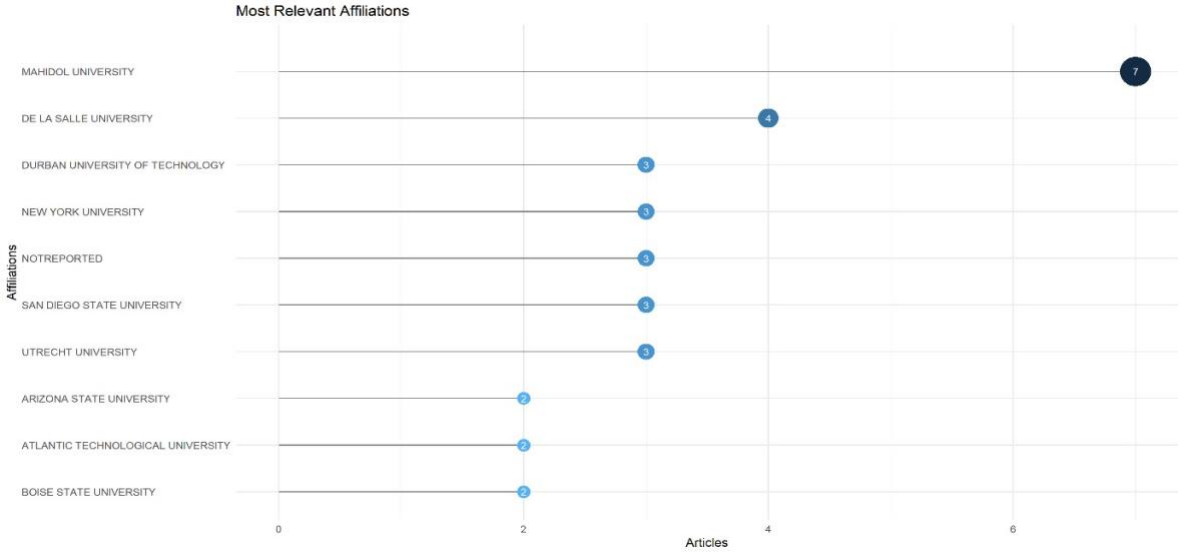
*Shvarts Anna* is the most prolific contributor in this dataset, having authored 3 papers. Several writers have each published two articles, including *Bernardo Allan B I*, Chikiwa Clemence, Crothers DS, Guo William, Maoto Satsope, Maphutha Kgaladi, Ngu Bing Hiong, Phan Huy P, and Villavicencio Felicidad T. This indicates a varied cohort of scholars contributing numerous publications to the dataset, with Shvarts Anna distinguished by possessing the greatest article count.

Figure 3
*Most Relevant Authors*




Mahidol University has the most contribution with 7 publications, while De La Salle University follows with 4 articles. Multiple institutions have each submitted three articles, including Durban University of Technology, New York University, San Diego State University, Utrecht University, and an unidentified university designated as Not Reported. Arizona State University, Atlantic Technological University, and Boise State University have each submitted two manuscripts. This indicates a wide array of institutional contributions, with Mahidol University emerging as the most productive in this dataset.

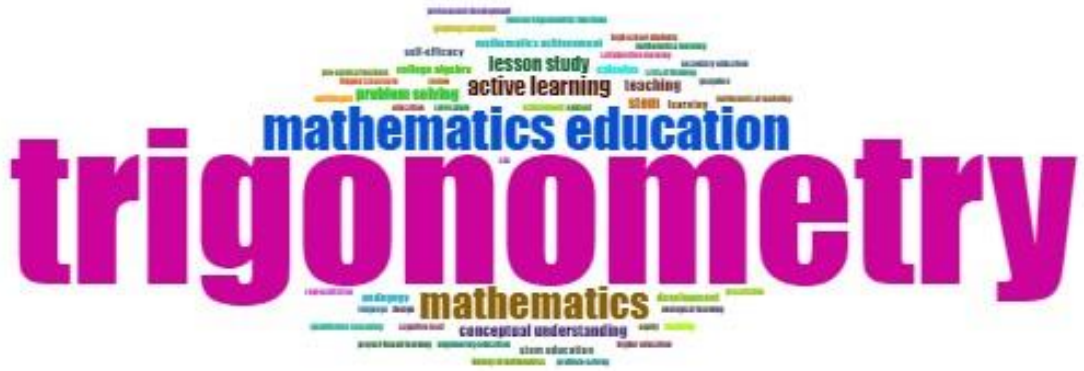
Figure 4
*Most Relevant Affiliations*




The term trigonometry is the most prevalent, occurring 51 times, signifying a significant emphasis on this subject. Mathematics education occurs 14 times, whereas mathematics appears 11 times. Other

notable terms are active learning, referenced 6 times, and lesson study, cited 5 times. Multiple words are referenced four times, including conceptual understanding, problem solving, STEM, and teaching. Finally, calculus is mentioned three times. These phrases emphasize important ideas and concepts in the research, with trigonometry as the predominant focus.

Figure 4
*Word Cloud*




**Discussion**

Trigonometry is a key foundational aspect in mathematics education, connecting numerous concepts and applications. Students struggle to master it due to traditional teaching techniques that emphasise rote learning over conceptual understanding (Mosese & Ogbonnaya, 2021; Urrutia et al., 2019). Studies suggest that using technology like GeoGebra can improve students' understanding of trigonometric functions and their applications (KepceoÄŸlu & Yavuz, 2016; Mosese & Ogbonnaya, 2021). Trigonometric ideas are also crucial for potential instructors since they affect their teaching effectiveness (Sekgoma, 2023). The collaborative aspect of this research emphasises the need for educators to exchange knowledge and innovate to enhance trigonometry student outcomes (Ngu & Phan, 2023). Thus, continued study and different teaching approaches are necessary to solve trigonometry's chronic problems and improve student understanding.

Trigonometry is important in mathematics education, as shown by its large academic literature. Articles in journals like the International Journal of Mathematical Education in Science and Technology and PRIMUS show ongoing study in this field, highlighting its importance in the curriculum (Urrutia et al., 2019). The presence of contributions from multiple institutions like Mahidol University and De La Salle University implies a collaborative effort to improve trigonometric pedagogy (Mosese & Ogbonnaya, 2021). According to prolific authors like Shvarts Anna are dedicated to addressing the challenges of teaching and mastering trigonometric principles. Research about trigonometry is crucial for designing effective teaching strategies to improve student knowledge and performance in trigonometry, a difficult topic (Sekgoma, 2023). The scholarly focus paid to trigonometry emphasises its importance in mathematics education and the need to continue exploring efficient teaching methods.

The term "trigonometry" appears 51 times in educational research, highlighting its importance in mathematics instruction. Trigonometry integrates algebra, geometry, and calculus, making advanced topics easier to learn (Jelatu et al., 2019; Naidoo & Govender, 2014; Wijaya et al., 2020). The frequent mention of "active learning" and "lesson study" suggests a shift towards novel trigonometric pedagogy that improves student engagement and comprehension (Asomah, 2023; Urrutia et al., 2019). Standard teaching approaches fail to explain trigonometric principles, causing student problems (Andika Sari & Nurfauziah, 2019; Subedi, 2021). Research shows that rote learning does not help pupils understand trigonometric relationships (Kurniati et al., 2022; Subedi, 2021). Research indicates that using technology like dynamic software and graphic calculators might enhance students' understanding of trigonometric functions and their applications (Dündar & Yaman, 2015; Maknun et al., 2021). The concentration on trigonometry in educational literature

reflects its usefulness in teaching mathematical thinking and problem-solving skills needed in many sectors, including STEM.

## 4. Conclusion

The century-long dataset (1924-2024) indicates a slight increase in research output, predominantly characterized by joint efforts, while international collaboration is still constrained. Trigonometry is emphasized as a central theme, referenced 51 times, underscoring its significance in mathematics instruction. Conventional pedagogical approaches have impeded students' conceptual comprehension; nevertheless, research indicates that the incorporation of technology, such as interactive software, might enhance educational results. The results underscore the necessity for ongoing innovation in pedagogical methods and collaboration among educators to tackle issues in trigonometry instruction, while also emphasizing the potential for increased international research initiatives.

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