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Uso de la Tecnología en la enseñanza de las matemáticas en educación básica: Análisis Bibliométrico y revisión literaria

Use of Technology in the Teaching of Mathematics in Primary Education: Bibliometric Analysis and Literary Review

Uso da Tecnologia no ensino de matemática na educação básica: Análise Bibliométrica e revisão literária

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Resumen

En los últimos años, el uso de la tecnología en la enseñanza de las matemáticas ha experimentado un crecimiento acelerado. La implementación de diversas herramientas busca mejorar los aprendizajes. Además, se orienta a potenciar el dominio tecnológico, generando una asociación que se transforma en conocimientos prácticos y aplicables a situaciones de la vida cotidiana. En este trabajo de investigación se realizó un análisis bibliométrico, es decir, un estudio cuantitativo sobre el uso de la tecnología en la enseñanza de matemáticas en el nivel básico. En el estudio se plantearon diez preguntas para explorar la relevancia, producción y citación del uso de herramientas digitales en la enseñanza de las matemáticas en el nivel básico, así como el impacto en la comunidad. La búsqueda se realizó en la base de datos *SCOPUS*, que arrojó 554 documentos. Finalmente, solo 16 artículos dieron respuesta a las interrogantes de investigación. Como resultado, se concluyó que las tecnologías potencian el impacto positivo en el aprendizaje de las matemáticas.

Palabras clave: Tecnología, enseñanza, matemáticas, educación básica, análisis bibliométrico.

Abstract

In recent years, the use of technology in the teaching of mathematics has experienced accelerated growth. The implementation of various tools seeks to improve learning. In addition, it is oriented to enhance technological mastery, generating an association that is transformed into practical knowledge applicable to everyday life situations. In this research work, a bibliometric analysis was carried out, that is, a quantitative study on the use of technology in the teaching of mathematics at the elementary level. Ten questions were posed in the study to explore the relevance, production and citation of the use of digital tools in the teaching of mathematics at the elementary level, as well as the impact on the community. The search was conducted in the SCOPUS database, which yielded 554 documents. Finally, only 16 articles provided answers to the research questions. As a result, it was concluded that technologies enhance the positive impact on mathematics learning.

Keywords: Technology, teaching, mathematics, basic education, bibliometric analysis.

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Resumo

Nos últimos anos, o uso da tecnologia no ensino de matemática tem experimentado um crescimento acelerado. A implementação de diversas ferramentas busca melhorar o aprendizado. Além disso, visa aprimorar o domínio tecnológico, gerando uma associação que se transforma em conhecimento prático aplicável às situações do dia a dia. Neste trabalho de pesquisa foi realizada uma análise bibliométrica, ou seja, um estudo quantitativo sobre o uso da tecnologia no ensino de matemática no nível básico. O estudo colocou dez questões para explorar a relevância, produção e citação do uso de ferramentas digitais no ensino de matemática no nível básico, bem como o impacto na comunidade. A busca foi realizada na base de dados SCOPUS, que rendeu 554 documentos. Por fim, apenas 16 artigos responderam às questões de pesquisa. Como resultado, concluiu-se que as tecnologias potencializam o impacto positivo na aprendizagem da matemática.

Palavras-chave: Tecnologia, ensino, matemática, educação básica, análise bibliométrica.

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Introduction

Information technologies play a vital role as they facilitate access to information, promote personalized teaching, encourage educational research, and prepare students for the future. Today's education not only improves efficiency and quality, but also promotes the preparation of students for a digitalized world Zhuoya & Tang (2022). The use of software in teaching mathematics significantly improves the efficiency of the learning process, as it is a motivating factor because it stimulates student interest by improving participation, communication, and feedback.

New techniques are increasingly being implemented that use e-learning with an emphasis on student self-development. New hybrid classrooms, understood as a model that combines face-to-face and virtual teaching, provide flexibility and accessibility, with the freedom to personalize knowledge, allowing students to advance at their own pace. The combination of face-to-face and virtual teaching generates new pedagogical strategies and technological resources that enrich the learning experience Shushuang (2019).

Therefore, it is essential that the methods and content of mathematics courses should include the use of information technology, which not only facilitates student learning but also provides them with the opportunity to acquire digital skills relevant to today's world Laitochová et al. (2022). Compared to traditional learning, the use of technology in teaching

has focus, flexibility and interaction with which teaching methodologies are adapted to the specific needs and contexts of students.

Emerging technologies that seek to improve the learning experience include: pedagogical models applied to e-learning of mathematics, online mathematics software, general e-learning tools, virtual communication and collaboration, online assessments, conferences, interactive teaching materials Cuypers (2012).

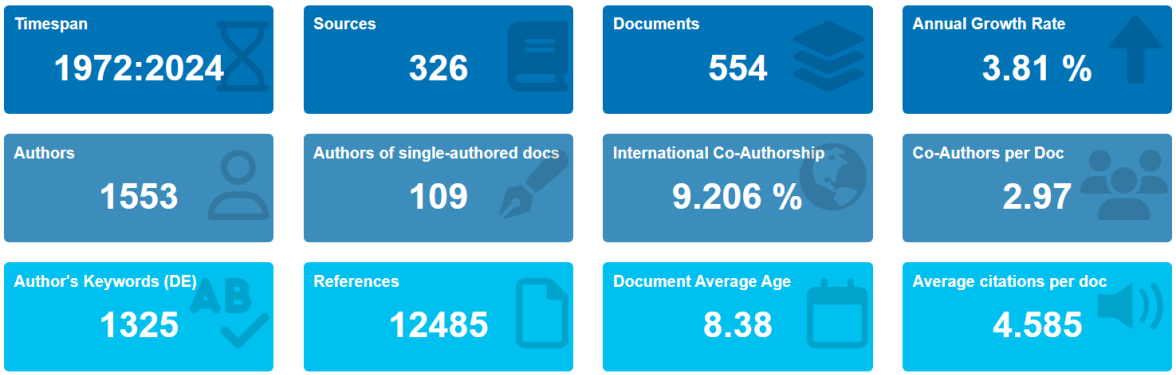
In this research work, a bibliometric analysis is carried out that answers the research questions; with the specific formula and the inclusion and exclusion criteria, the number of works that contribute to the topic is delimited, resulting in 16, this allows focusing the area, providing a comprehensive and updated vision on the use of technology in the teaching of mathematics.

Material and Methods

Scopus database . The sensitive search formula, which consists of key terms to optimize the retrieval of relevant documents, was formed as follows: TITLE-ABS-KEY (technologies and teaching and education and basic and mathematics). For the analysis of bibliometric information, the *VOSviewer* and B*ibliometrix software were used* . Figure 1 shows a descriptive summary of the work carried out.

In the time periods from 1972 to 2024, 554 documents were obtained from 326 sources. The annual growth rate was 3.81%, the participation of 1553 authors and a co-authorship rate of 9.2%. 1325 keywords were identified, with an average of 4.5% citations per document and a total of 12,485 references.

Figure 1. Descriptive summary of the works analyzed



Source: own elaboration

The analysis was carried out in five main phases:

1. Formulation of research questions: The main objectives and problems were defined.
2. Search: Sensitive formula was applied to collect relevant documents.
3. Inclusion and exclusion criteria: Only works that met high standards of quality and relevance were selected.
4. Selection and collection of information: The selected documents were analyzed in detail.
5. Results: The data were interpreted to answer the research questions.

Each phase is described in detail below:

Phase 1. Research questions

Within this phase, ten research questions were selected to support the study carried out. A global and individual analysis is sought for each approach. This analysis builds a theoretical framework that will serve as support for future researchers who require the review of reliable works to answer questions similar to those proposed.

The questions were posed as follows:

1. What is the annual scientific production?
2. What is the average number of appointments per year?
3. What are the most relevant sources?
4. How has font production evolved over time?
5. Who are the most relevant authors?
6. What is the scientific production of the countries?
7. What are the most commonly used keywords in the studies reviewed?
8. What impact does the use of software have on the teaching of mathematics?
9. How does the use of technology in teaching mathematics affect students ?
10. How does teacher training and education influence the effective use of technology in teaching mathematics in basic education ?

Phase 2. Search process

Scopus database was selected for the search of articles due to its broad scope in academic and scientific publications. For the search, a sensitive formula was used, designed to optimize the retrieval of relevant documents. The formula was constructed as: TITLE-ABS-KEY ('technologies', 'teaching', 'education', 'basic' and 'mathematics'), covering terms

in the title, keywords and abstracts of the documents. Subsequently, the analysis of the retrieved data was performed using the *VOSviewer* and *Bibliometrix software* .

Phase 3. Inclusion and exclusion criteria

Within this phase, the specific formula is built, which is key to defining the works that answer the research questions, being as follows TITLE-ABS-KEY (technologies AND teaching AND education AND basic AND mathematics) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024)) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (OA , "all")), for the selection the inclusion and exclusion criteria were used (Table 1).

Table 1. Inclusion and exclusion criteria

Inclusion	Exclusion
- Investigations from five years to date. - Title, abstract and keywords containing the terms: technologies and teaching and basic education and mathematics - English language. - Research articles and open access.	- Research not in English. - Duplicate publications. - Articles with systematic reviews. - Articles without open access. - Topics outside the education sector.

Source : own elaboration

Phase 4. Selection and collection of information

According to the results obtained from the general search, 554 documents were found, which were analyzed to answer the research questions. To do so, filters were applied for similarity, quality, conceptual clarity, population characteristics, samples, findings and conclusions, resulting in a total of 16 papers (Table 2).

Table 2. List of articles selected after analysis.

No.	Article	Authors and year
1	A science, technology, engineering, and mathematics dialogue reading program for early grades: Developing a conceptual framework.	Bezuidenhout (2021).
2	Assistive technology in the construction of numerical concepts: a study involving actions of teachers and students with visual impairments.	Sganzerla & Geller (2020).
3	ATS-STEM: A comprehensive teaching methodology to improve the skills of secondary school students.	Fernandez-Morante et al. (2022)
4	Constructivist-led assistive technology: An experiment in a Namibian special primary school	Abiatal & Howard (2020).
5	Develop a science, technology, engineering and mathematics-based learning environment for future early childhood teacher training educators.	Efriani et al. (2023).
6	Third grade students' performance and development of conceptual understanding in technology-enhanced instruction with interaction Mathematics software	Uwineza et al. (2023).
7	Integrating technologies in teaching and learning mathematics at the beginning of secondary education in Austria	Weinhandl et al. (2021).
8	Intelligent System for Interactive Teaching through Video Games	Robles & Quintero M. (2020).
9	Introducing the PDI to future mathematics teachers: an evaluation using the TPACK framework	Gonzales & Gonzales (2021).
10	Is it possible for young students to learn AI-STEAM application with experiential learning?	Hsu et al. (2021).
11	Mathematical modelling in secondary chemistry Education: Chromatography	Kraska (2020).
12	Poly-Universe resource for solving geometric tasks by Portuguese students of basic education	Matos et al. (2023).
13	Expertise of the Mathematics teacher to teach through modelling using ICT	Padilla et al. (2022).

14	The Impact of the EDUKA Virtual Learning Platform on the Academic Performance of Primary School Children.	Kliziene et al. (2021).
15	The perspective of public school mathematics teachers on their knowledge and teaching practice in Connection with the Bncc	Souza & Lopes (2021).
16	Using Edpuzzle to learn polynomial factorization for secondary school.	Jimenez et al. (2021).

Source: own elaboration

Results

According to the analysis carried out and the application of the exclusion criteria, 16 papers were obtained, which provide answers to the research questions. It is worth mentioning that the analysis of documents was only carried out in the *Scopus database* , which initially yielded 27 papers obtained from the specific formula; 11 papers did not meet the criteria of quality, clarity, similarity, therefore, they did not provide an answer to the research question.

Question 1: What is the annual scientific output?

In 2019, the number of published articles increased with 55, and then dropped with 46 in 2023. Currently, as of March 2024, seven papers have been published. Table 4 shows that over the years there has been considerable growth in research work related to the use of information technologies in the teaching of mathematics. Figure 2 shows the annual scientific production, highlighting the increase in 2019 and the subsequent decline in 2023.

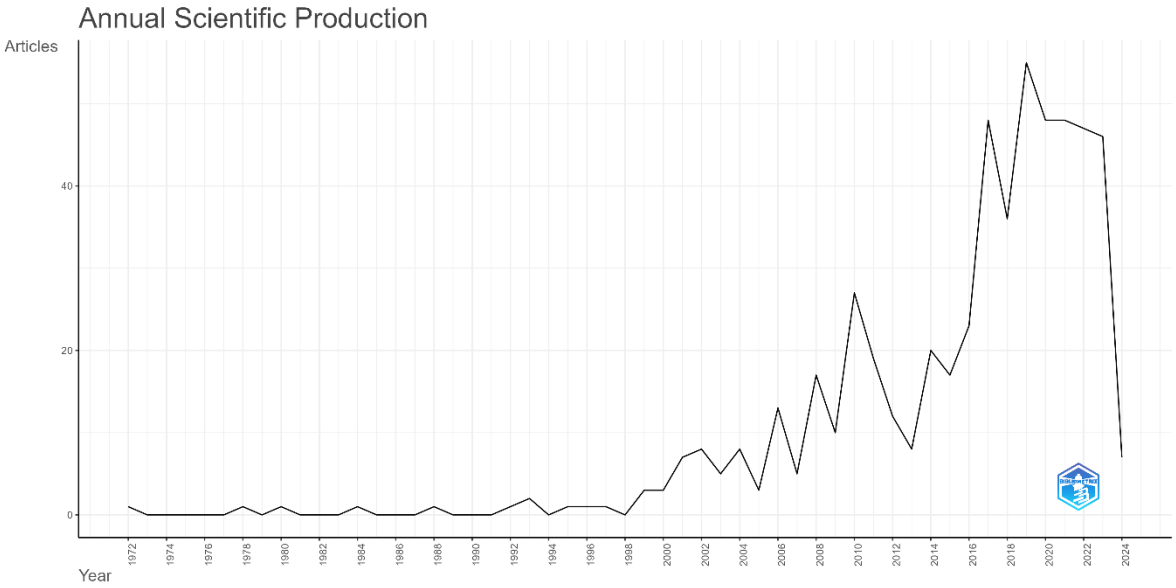
Question 2: What is the average number of appointments per year?

This metric is used to assess the influence and relevance of an article in its field of study. The first publication on this topic was made in 1972, and has had an annual average of citations of 0.06%, by 2012 it had a growth of 0.7, in 2016 it reached 0.9 and in 2021 its best year with 1.3%, therefore, considerable growth is observed in recent years (Figure 3).

Question 3: What are the most relevant sources?

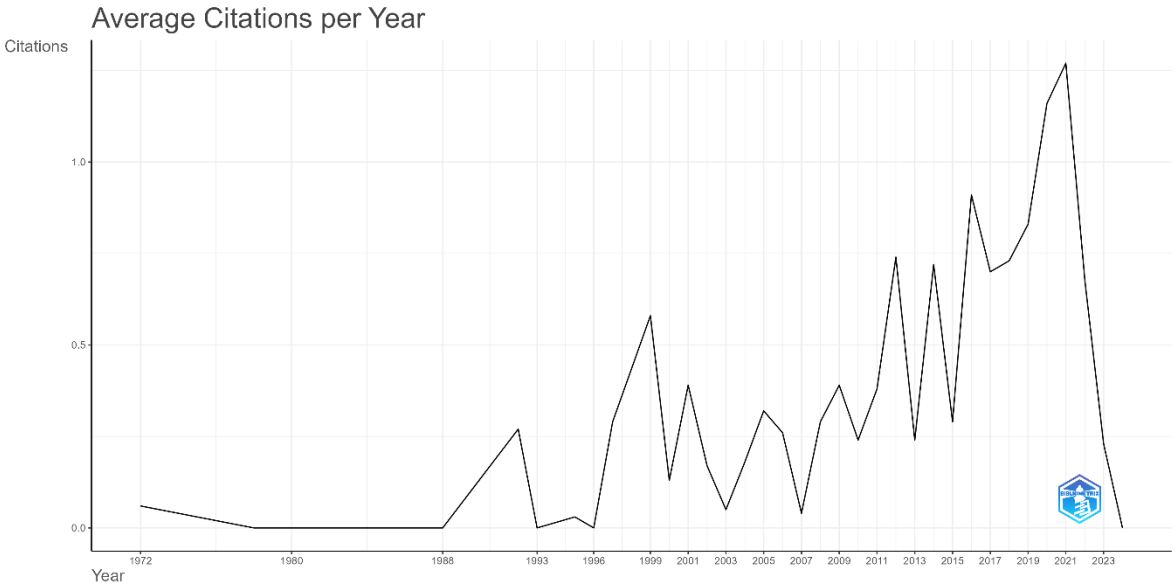
Question 4: How has font production evolved over time?

Figure 2. Annual scientific production



Source: Prepared by the author using Bibliometrix software.

Figure 3. Average number of citations per year.

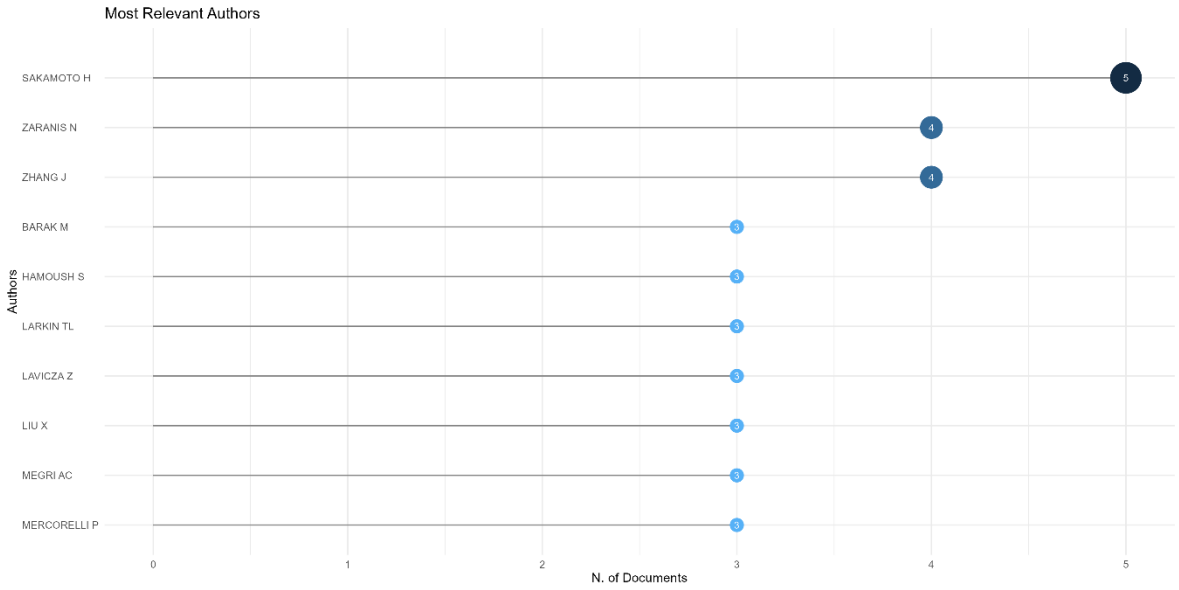


Source: Prepared by the author using Bibliometrix software.

Question 5: Who are the most relevant authors?

Sakamoto H is in first place with six publications, which indicates the individual contribution of the author. In second place is Zaranis N, with four papers. In third place is Zhang J, with four publications, these are the authors who lead the world publications on the research topic (Figure 4).

Figure 4. Most relevant authors

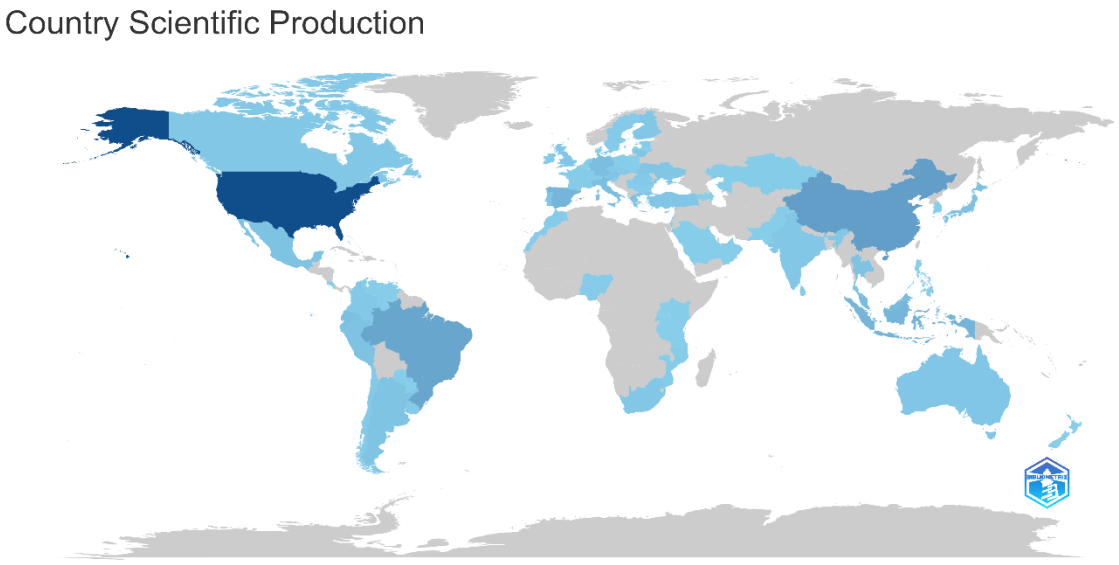


Source: Own elaboration using Bibliometrix software

Question 6: How has font production evolved over time?

Regarding the scientific production of countries, the United States has a frequency of 344 documents, behind China with 122, followed closely by Brazil with 103, these three countries remain at the top in the production of research work worldwide (Figure 5).

Figure 5. Scientific production of the countries

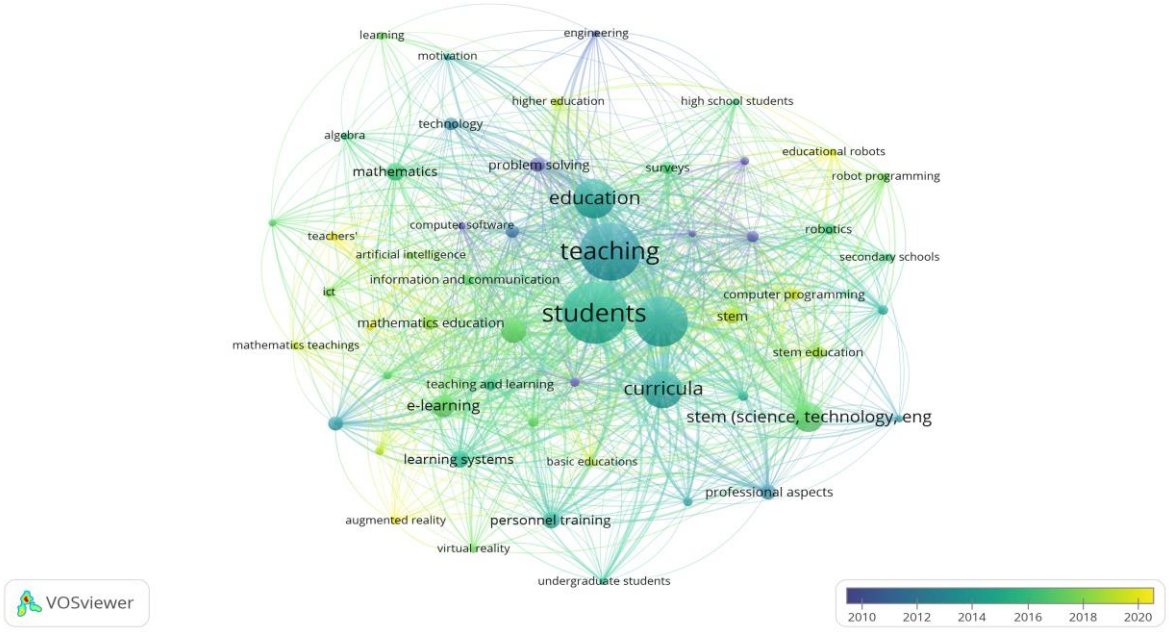


Source: Own elaboration using Bibliometrix software

Question 7: What are the most used keywords in the reviewed studies?

The most used keywords in research papers from 2010 to date are: *student* with 251 occurrences and 1151 total links to 2014; *teaching* has 228 occurrences and 1072; engineering *education* shows 186 occurrences and 877. From 2020 to date the words: *STEM education* , *computer programming* , *mathematics teaching* have gained strength within the new publications (Figure 6).

Figure 6. Most frequently used words



Source. Own creation Vosviewer software.

Question 8: What impact does the use of software have on the teaching of mathematics?

New technologies have had positive effects on students' mathematical performance, it can improve the understanding of concepts, increase students' motivation Abiatal & Howard (2020). Educational and interactive mathematics software can provide dynamic visual representations, helping students to understand abstract concepts in a concrete way Efriani et al. (2023), Uwineza et al. (2023), Weinhandl et al. (2021).

Question 9: How does the use of technology in teaching mathematics affect students?

Technology such as educational software and interactive applications can make learning mathematics more engaging and stimulating, which increases motivation and engagement. Compared to traditional teaching methods, the use of technology in mathematics education can provide students with additional tools and resources that complement and enrich their learning experiences, thereby improving academic performance and a better understanding of mathematical concepts, access to a wide range of online educational resources such as: tutorials, explanatory videos and interactive exercises. (Robles y Quintero M., 2020; Fernández-Morante et al., 2022).

Question 10: How does teacher training and education influence the effective use of technology in teaching mathematics in basic education ?

Teacher training plays a fundamental role in the effective use of technology in the teaching of mathematics in basic education, it can influence a change in pedagogical approach, encouraging student-centered practices and promoting critical and reflective use, which can result in better performance and a more enriching educational experience Gonzales y Gonzales (2021), technology training enables teachers to use tools in the assessment of learning, providing timely and effective feedback to improve the teaching-learning process Kraska (2020).

Continuous training and education allows teachers to keep up to date with the latest trends and technological tools, helping them to improve their practices and adapt to changes in the educational environment Matos et al. (2023). It is essential that teachers have the ability to address mathematical content in a didactic and pedagogical way, allowing for more interactive and practical teaching for students.

Discussion

According to the review of the works found, the use of technology in the teaching of mathematics can have a positive impact on the academic performance of students. Various authors (Souza y Lopes, 2021; Jimenez et al., 2021; Matos et al., 2023)agree that the use of specialized software in the teaching of mathematics facilitates the understanding of concepts, personalizes learning and provides immediate feedback, which increases student motivation and commitment.

Along the same lines, Persano Adorno et al. (2021)they suggest that the use of software in teaching mathematics can improve students' understanding, motivation and engagement, personalize learning, provide additional practice and immediate feedback, and develop technological skills.

Current trends Weinhandl et al. (2021),include independent practice through digital tasks with real-time feedback, tailored to the individual needs of students. Similarly,Uwineza et. al. (2023) They say some software programs allow for customized activities that fit each student's specific pace and abilities.

Based on the studies analyzed, the authors agree that the use of software in the teaching of mathematics in basic education improves the understanding of the basic concepts of mathematical language and encourages a more interactive and personalized approach.

Conclusions

The study carried out answers the research questions raised; the international impact in relation to the use of software as support in the teaching of mathematics in basic education gains strength over the years. According to the database analyzed, from its origins in 1972 to date it has had accelerated growth. In 2019, the largest number of published works was recorded, with a total of 55. The countries that carry out the most research are the United States, with 344 documents, closely followed by China, with 122.

Impact on students: The software helps students, making them more interactive and dynamic, motivating them to continue acquiring meaningful knowledge. In addition, it allows them to correct errors and understand concepts by developing skills, enriching and forming new learning experiences appropriate to their pace and way of working with personalized activities and exercises.

Comparison with traditional methods: the use of technology in teaching mathematics generates greater interactivity and participation of students, actively involving them and improving their understanding, personalizing their learning by adapting content and methodologies to their individual needs, as well as access to online resources with a wide range of materials.

Teacher training: Equipping teachers with technological skills and knowledge helps to enhance the positive impact of technology on student learning and enrich the educational experience in the classroom.

Ethical Considerations: Equity and access to technology are essential to ensure equality, privacy and data protection, that information collected through technological tools is handled securely and complies with data protection regulations, promoting responsible and ethical use, and contributing to an inclusive, safe and quality educational environment.

Future lines of research

The advancement of technology offers multiple opportunities to explore the impact of tools such as *Artificial Intelligence* (e.g., personalized tutoring algorithms), Augmented Reality (applications to visualize mathematical concepts), Virtual Reality (immersive environments for solving problems), and *Gamification* (interactive educational games) on basic mathematics learning. It is recommended that future research should focus on longitudinal studies to assess how these technologies can improve conceptual understanding and academic performance in the long term.

In turn, teacher training in the use of technological tools is a critical factor for their effective implementation in the classroom. It is necessary to explore how continuing training can address the needs of teachers in areas such as curricular integration, the design of interactive activities and the management of digital platforms, ensuring effective implementation in the classroom.

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