TRENDS IN IMPLEMENTATION OF TECHNOLOGY USE IN MATHEMATICS EDUCATION ON SCOPUS DATABASE: BIBLIOMETRIC ANALYSIS

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Abstract. This study aims to analyze the trend of technology implementation in mathematics education in the Scopus Database using bibliometric analysis. Using predetermined keywords, researchers analyzed 251 documents using RStudio and Vosviewer. From the analysis conducted, it can be concluded that this study shows an exciting growth pattern in research on the use of technology in mathematics education over the period 1977 to 2024. This pattern changed significantly in the last 15 years, from 2009 to 2024, equivalent to four times the previous figure, or 66.13% of the total. The University of Pretoria dominated with the most publications, at 14 articles. "Educational Studies in Mathematics" stands out as the best source with the highest h-index, at 5. Marien Alet Graham stands out as the author with the highest h-index, at 3. The paper by Drijvers et al. (2010) stands out with the highest number of citations, at 168. There were 46 keywords divided into 6 groups, with the keywords Whatsapp, Geogebra, Science Technologies, and Collaborative Learning potentially being exciting and innovative research subjects related to Technology in Mathematics Education.
Keywords: *Technology, Mathematics Education, Bibliometric*

1. INTRODUCTION

Education has a crucial role in advancing society and developing individual potential [1], [2], [3]. Through education, everyone is given the opportunity to access the knowledge, skills and understanding necessary to achieve success in life [4], [5]. Skills acquired through education enable a person to contribute positively to society and the economy. Apart from that, education also opens the door to a deeper understanding of the world around us, broadens our horizons, and fosters a critical and analytical attitude [6], [7], [8]. Thus, the existence of education is not only important for individual development, but also for collective progress and overall social welfare.

One area that is experiencing rapid development is mathematics education. Mathematics education is not just about studying formulas and theories, but has also developed into a discipline that emphasizes understanding concepts, problem solving, and application in real world contexts [9], [10], [11], [12]. Through modern mathematics education, students are not only taught to calculate, but also to understand the basic concepts underlying mathematics and how to apply them in various situations of everyday life as well

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as in the context of science and technology [13], [14], [15]. Thus, mathematics education is not only a means to develop logical and analytical thinking skills, but also to prepare individuals to face complex challenges in the era of globalization and information technology [16], [17], [18].

One interesting aspect related to mathematics is the use and implementation of technology in mathematics education. This is due to the ability of technology to expand and enrich the mathematics learning experience for students [19], [20], [21]. Through the use of special software, mobile applications, and online learning platforms, students can access mathematics material in a more interactive and interesting way [22], [23], [24], [25]. In addition, technology also allows the adoption of more varied learning methods, such as 3D visualization, simulations, and educational games, which help students understand mathematical concepts better [26]. The use of technology in mathematics education also facilitates problem-based and collaborative learning, where students can work together to solve mathematical challenges as a team [27], [28], [29], [30]. Thus, the integration of technology in mathematics education not only increases students' interest in learning, but also enriches their overall learning experience.

The use of technology in the context of mathematics education has encouraged the author to conduct a lot of research which is documented in the Scopus database. Through bibliometric analysis, the author can explore the latest developments in the field, identify research trends, and understand the contribution of researchers and institutions to the development of mathematics related to the application of technology. This analysis helps in gaining in-depth insight into the direction of development of mathematics education supported by technology, as well as making it possible to find new opportunities in research that can have a positive impact on mathematics learning in the future.

2. RESEARCH METHOD

This research aims to analyze bibliometrics regarding trends in technology use in the context of mathematics education. Bibliometrics is a quantitative analysis method used to evaluate scientific literature with a focus on the quantity, quality and impact of the scientific work [31], [32]. In searching for documents in the Scopus database, researchers used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method to eliminate irrelevant results and ensure accuracy and objectivity in data collection. With this approach, this research seeks to provide a comprehensive picture of developments and trends in the use of technology in mathematics education based on careful and structured bibliometric analysis.

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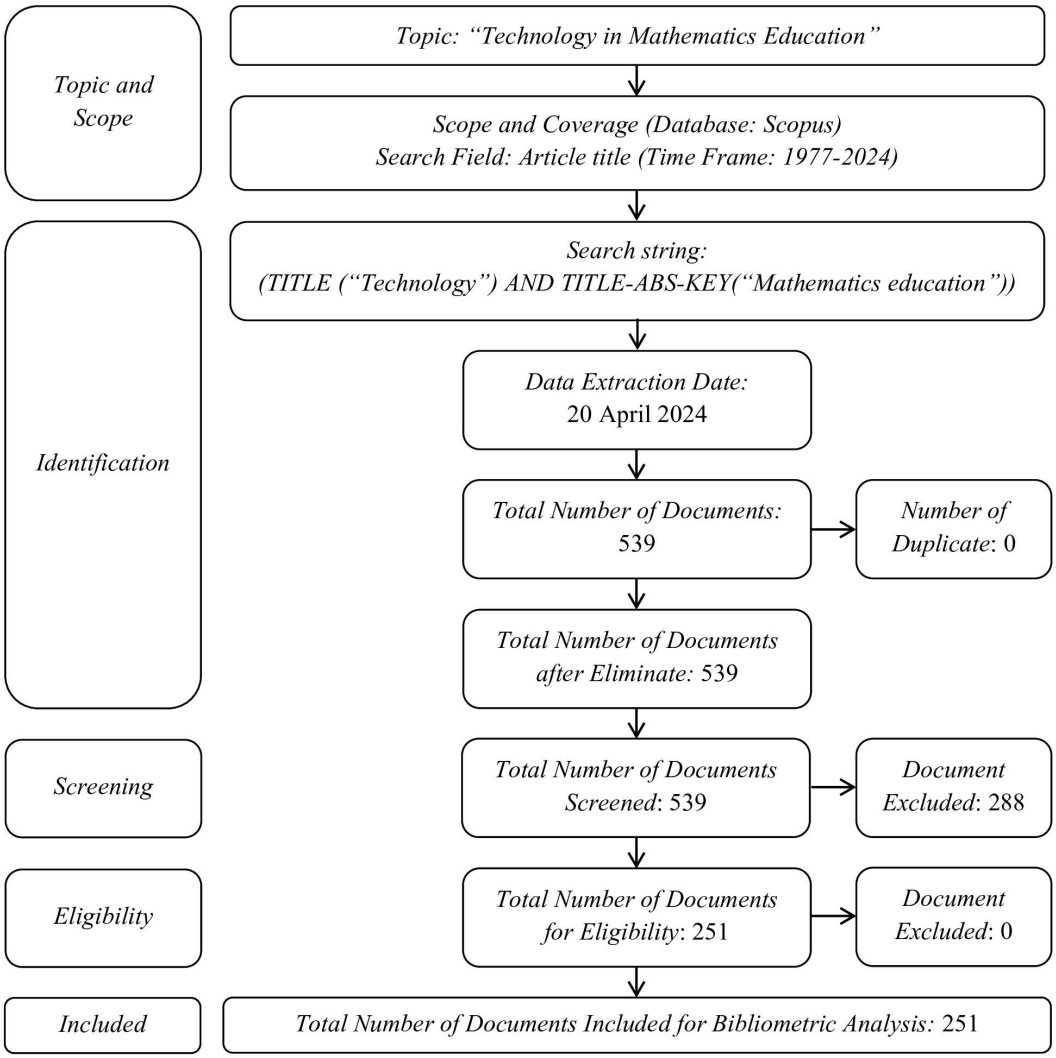

Figure 1. Bibliometric Flow Using PRISMA Method

This research adopts a predetermined topic, namely "Technology in Mathematics Education". Through the use of keywords (TITLE ("Technology") AND TITLE-ABS-KEY ("Mathematics education")) in the identification process, 539 related documents were successfully found. Next, the author carried out filtering using the criteria "Article" and the type "Social Sciences", which resulted in 251 documents that passed the selection and remained relevant until the inclusion stage. Next, all documents were analyzed using RStudio and Vosviewer. Thus, this research has a solid database for conducting bibliometric analysis of the use of technology in mathematics education, which will hopefully provide valuable insights into trends and developments in the domain.

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3. RESULTS AND DISCUSSION

3.1 Results

Researchers conducted an analysis using RStudio which aims to see publication trends, best affiliations, best authors, best sources, and documents with the highest citations.

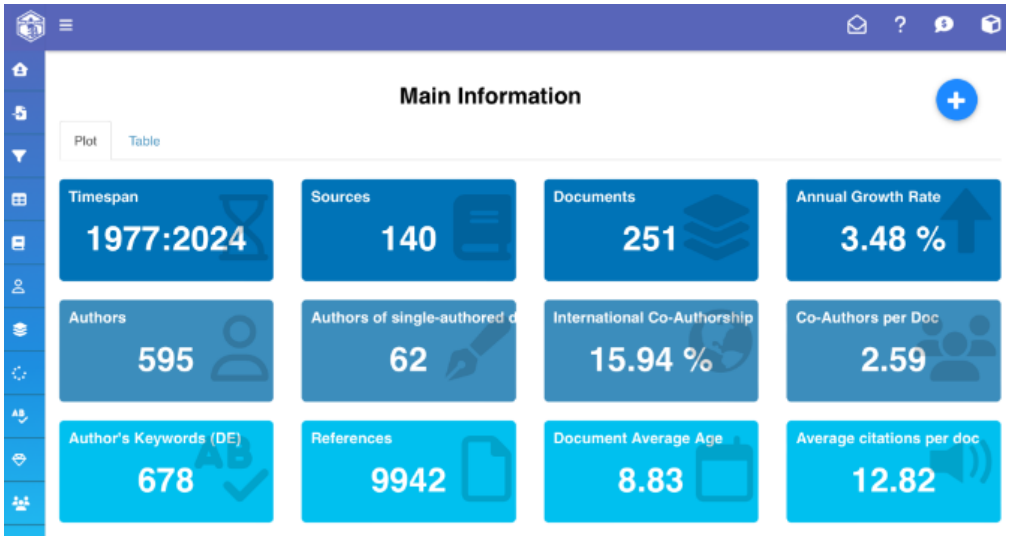

Figure 2. Main Information

This research covers a wide time span, from 1977 to 2024, and succeeded in collecting 140 sources that contributed to 251 articles relevant to the topic "Technology in Mathematics Education". The growth of this research has proven positive with an Annual Growth Rate reaching 3.48%, indicating continued interest and focus in this domain over the last few decades. Involving a total of 595 authors, of which 62 are sole authors, indicates significant collaborative work in advancing knowledge in this area. In addition, international author participation of 15.94% indicates that the issue of using technology in mathematics education has a global impact and attracts interest from various parts of the world. In terms of references, this study collected 9942 references that support bibliometric analysis, demonstrating the depth of literature available in this domain. In addition, the creation of 678 keywords shows the diversity of topics and research focuses that exist in the related literature. Thus, the data collected through this bibliometric analysis provides a strong foundation for understanding trends, developments and dynamics of technology use in the context of mathematics education.

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Publication Trends

Table 1. Publication Trends by Years

Year	Articles	Percentage	Year	Articles	Percentage
1977	1	0.40%	2003	3	1.20%
1978	-	-	2004	1	0.40%
1979	1	0.40%	2005	4	1.59%
1980-1983	-	-	2006	4	1.59%
1984	1	0.40%	2007	4	1.59%
1985	-	-	2008	2	0.80%
1986	2	0.80%	2009	2	0.80%
1987	1	0.40%	2010	10	3.98%
1988	-	-	2011	10	3.98%
1989	1	0.40%	2012	5	1.99%
1990	1	0.40%	2013	11	4.38%
1991	-	-	2014	7	2.79%
1992	1	0.40%	2015	11	4.38%
1993-1994	-	-	2016	13	5.18%
1995	3	1.20%	2017	9	3.59%
1996	1	0.40%	2018	14	5.58%
1997	1	0.40%	2019	13	5.18%
1998	1	0.40%	2020	25	9.96%
1999	-	-	2021	23	9.16%
2000	2	0.80%	2022	22	8.76%
2001	3	1.20%	2023	31	12.35%
2002	2	0.80%	2024	5	1.99%

Source: RStudio

This research shows an interesting growth pattern in research on the use of technology in mathematics education over the period 1977 to 2024. From 1977 to 2009, only 40 articles were documented, which only accounted for 15.93% of the total articles analyzed. However, this pattern changed significantly in the last 15 years, from 2009 to 2024, where the number of articles published increased dramatically to 166 articles, which is equivalent to four times the previous figure, or 66.13% of the total. This significant jump in the number of publications indicates an increasing interest and focus in research related to the use of technology in mathematics education, perhaps in line with advances in information and communication technology and paradigm shifts in learning methods. Thus, the growth trends observed in these two periods highlight the importance of this issue within the research community, as well as indicating the potential for further developments in the future.

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Affiliation with the Highest Publication

Table 2. Top 10 the Affiliation with the Highest Publication

No	Affiliation	City	Country	TP
1	University of Pretoria	Pretoria	South Africa	14
2	The Chinese University of Hong Kong	Hong Kong	Hong Kong	12
3	Arizona State University	Tempe	United States	7
4	Brigham Young University	Provo	United States	7
5	Achva Academic College	Nahalal	Israel	6
6	University of Central Florida	Orlando	United States	6
7	Utrecht University	Utrecht	Netherlands	6
8	Virginia Commonwealth University	Richmond	United States	6
9	Branch of Tyumen Industrial University in Noyabrsk	Noyabrsk	Russia	5
10	Cyprus University of Technology	Limassol	Cyprus	5

Description: TP=Total of Publication

The University of Pretoria dominates with the highest number of publications, namely 14 articles, showing a significant contribution to research on the use of technology in mathematics education. In addition, other universities also made significant contributions, such as The Chinese University of Hong Kong and Arizona State University, with 12 and 7 publications respectively. Overall, affiliated universities from various countries, including the United States, Netherlands, Russia, Israel, and Cyprus, have played a role in contributing understanding and research on the use of technology in the context of mathematics education. This shows the diversity in perspectives and approaches applied in exploring this issue globally, as well as the importance of cross-institutional collaboration to expand the scope of knowledge and understanding in this important domain.

Source with the Highest H-index

Table 3. Top 10 Best Sources with the Highest H-index

No	Journal	SR	Publisher	Country	h	TC	TP
1	Computers in the Schools	Q2	Routledge	United States	5	91	12
2	Education and Information Technologies	Q1	Kluwer Academic Publishers	United States	5	80	6
3	Educational Studies in Mathematics	Q1	Springer Netherlands	Netherlands	5	289	7
4	Computers and Education	Q1	Elsevier Ltd	United Kingdom	4	224	5

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No	Journal	SR	Publisher	Country	h	TC	TP
5	Eurasia Journal of Mathematics, Science and Technology Education	Q2	Modestum LTD	Turkey	4	68	6
6	Mathematics Education Research Journal	Q1	Springer Netherlands	Netherlands	4	111	4
7	ZDM - International Journal on Mathematics Education	Q1	Springer Verlag	Germany	4	57	8
8	Bolema - Mathematics Education Bulletin	Q3	BOLEMA Departamento de Matematica	Brazil	3	14	4
9	Education Sciences	Q2	Multidisciplinary Digital Publishing Institute (MDPI)	Switzerland	3	31	7
10	International Journal of Mathematical Education in Science and Technology	Q2	Taylor and Francis Ltd.	United Kingdom	3	68	12

Description: h=h-index, TC=Total Citation, TP=Total Publication

In the data provided, “Educational Studies in Mathematics” stands out as the best source with the highest h-index of 5, indicating a significant impact in the academic literature in the field of mathematics education. However, it is important to note that each journal on the list makes important contributions to enriching discussion and understanding in this field. For example, "Computers and Education" and "Mathematics Education Research Journal" are also important journals with a fairly high h-index, although slightly below "Educational Studies in Mathematics". Each journal provides a platform for high-quality research, analysis, and critical thinking that supports the development of mathematics education globally. Thus, while one source may stand out on some particular metrics, the overall contributions from multiple journals create diversity and depth in the scholarly literature in the field of mathematics education.

Author with the Highest H-index

Table 4. Top 10 Author with the Highest H-index

No	Name	Affiliation	Country	h	TC	NP
1	Marien Alet Graham	University of Pretoria	South Africa	3	14	4
2	Uffe Thomas Jankvist	Aarhus University	Denmark	3	20	3
3	Qing Li	University of Calgary	Canada	3	58	3
4	Morten Misfeldt	Aalborg University Copenhagen	Denmark	3	36	3

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No	Name	Affiliation	Country	h	TC	NP
5	Petronella Elize Saal	University of Pretoria	South Africa	3	11	3
6	Aibhín Bray	The University of Dublin	Ireland	2	181	2
7	Sarah Bush	University of Central Florida	United States	2	30	2
8	Chantal Buteau	Brock University	Canada	2	23	2
9	Paul Drijvers	Utrecht University	Netherlands	2	226	3
10	Michael Eichmair	Universität Wien	Austria	2	5	2

Description: h=h-index, TC=Total Citation, TP=Total Publication

In the data provided, Marien Alet Graham stands out as the author with the highest h-index, namely 3, indicating the significant impact of her work in the scientific literature. However, each author on the list has made important contributions to enriching knowledge and understanding in their respective fields. For example, Paul Drijvers and Qing Li also have quite high h-indexes, indicating significant contributions to the academic literature. Nonetheless, each author, such as Uffe Thomas Jankvist and Sarah Bush, makes valuable contributions through their research, analysis, and ideas. The diversity of the authors' backgrounds and institutions reflects cross-border collaboration and diverse contributions to knowledge building around the world. Therefore, while one author may stand out on some particular metrics, the collective contributions of all authors create diversity and depth in the scholarly literature in the field of mathematics education.

Document with the Highest Citation

Table 5. Top 10 Document with the Highest Citation

No	Citation	Title	Total Citation
1	[33] (Drijvers et al., 2010)	The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom	168
2	[34] (Roschelle et al., 2010)	Integration of technology, curriculum, and professional development for advancing middle school mathematics: Three large-scale studies	147
3	[35] (Bray & Tangney, 2017)	Technology usage in mathematics education research–A systematic review of recent trends	127
4	[36] (Park et al., 2017)	Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics	99
5	[37] (Lee et al., 2020)	Computational thinking from a disciplinary perspective: Integrating	92

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No	Citation	Title	Total Citation
		computational thinking in K-12 science, technology, engineering, and mathematics education	
6	[38] (Ritz & Fan, 2015)	STEM and technology education: International state-of-the-art	92
7	[39] (Langen & Dekkers, 2005)	Cross-national differences in participating in tertiary science, technology, engineering and mathematics education	81
8	[40] (Craig et al., 2013)	The impact of a technology-based mathematics after-school program using ALEKS on student's knowledge and behaviors	69
9	[41] (Alexander & Hermann, 2016)	African-American women's experiences in graduate science, technology, engineering, and mathematics education at a predominantly White university: a qualitative	65
10	[42] (Reinhold et al., 2020)	Learning fractions with and without educational technology: What matters for high-achieving and low-achieving students?	59

Source: RStudio

In the list presented, the paper Drijvers et al., (2010) stands out with the highest number of citations, namely 168. However, each paper in this list makes an important contribution in enriching the understanding and discussion of the use of technology in mathematics education. Papers such as Roschelle et al., (2010) and Bray & Tangney, (2017) also have a significant number of citations, 147 and 127 respectively. These papers together form a solid foundation of knowledge and provide valuable insights for researchers, practitioners and policy makers in an effort to increase the effectiveness of the use of technology in mathematics education. Thus, while one paper may stand out in terms of number of citations, the overall contribution of all the documents in this list creates diversity and depth in the academic literature in the field.

Focus Research and Keywords Novelty

After analyzing using RStudio, the researcher then analyzed using Vosviewer to look for groupings and novelty of keywords.

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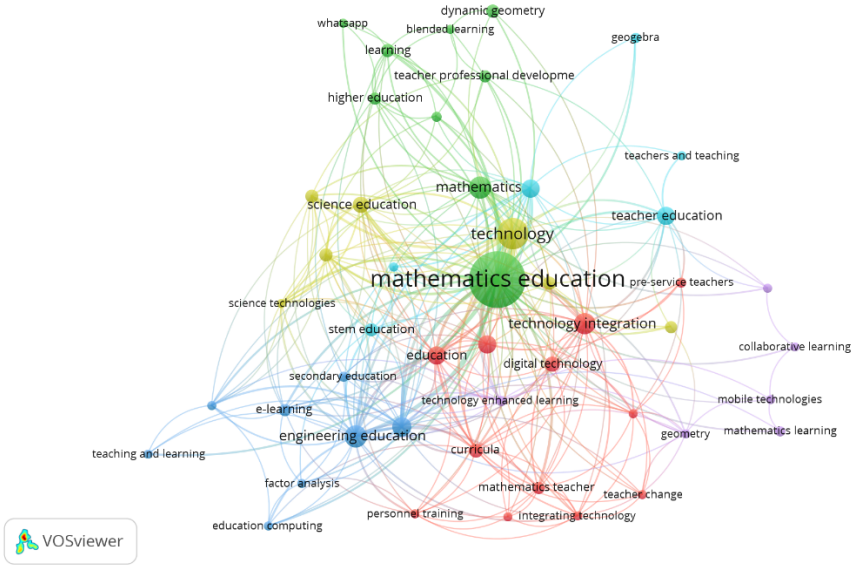

Figure 3. Focus Research

From the analysis results, there are 46 keywords divided into 6 groups. Next, the researcher names each group according to the grouping of keywords.

Table 6. Keyword Grouping per Cluster

No	Color	Cluster Name	Keywords
1	Red (11 keywords)	Digital Technology Integration in Mathematics Education	Curricula, Digital Technology, Education, Educational Technology, Integrating Technology, Mathematics Teacher, Personnel Training, Pre-service Teacher, Secondary Mathematics, Teacher Change, Technology Integration
2	Green (8 keywords)	Innovative Mathematics Education through Blended Learning	Blended Learning, Dynamic Geometry, Higher Education, Innovation, Learning, Mathematics, Mathematics Education, Teacher Professional Development, Whatsapp
3	Dark blue (8 keywords)	Enhancing Mathematics Education through Educational Technology	Computer Aided Instruction, E-learning, Education Computing, Engineering Education, Factor Analysis, Secondary Education, Students, Teaching and Learning

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No	Color	Cluster Name	Keywords
4	Yellow (7 keywords)	Interdisciplinary Approach to STEM Education Technology	Science, Science Education, Science Technologies, STEM, Technology, Technology Education, TPACK
5	Purple (6 keywords)	Enhancing Mathematics Learning through Collaborative Mobile Technologies	Collaborative Learning, Geometry, Mathematics Learning, Mobile Technologies, Problem Solving, Technology Enhanced Learning
6	Navy blue (6 keywords)	Geogebra Integration in Teacher Professional Development for STEM Education	Geogebra, Professional Development, STEM Education, Teacher Beliefs, Teacher Education, Teacher and Teaching

Source: Vosviewer

After getting the keyword groupings, the next step is to find keywords that are not used too much in the Overlay Visualization menu.

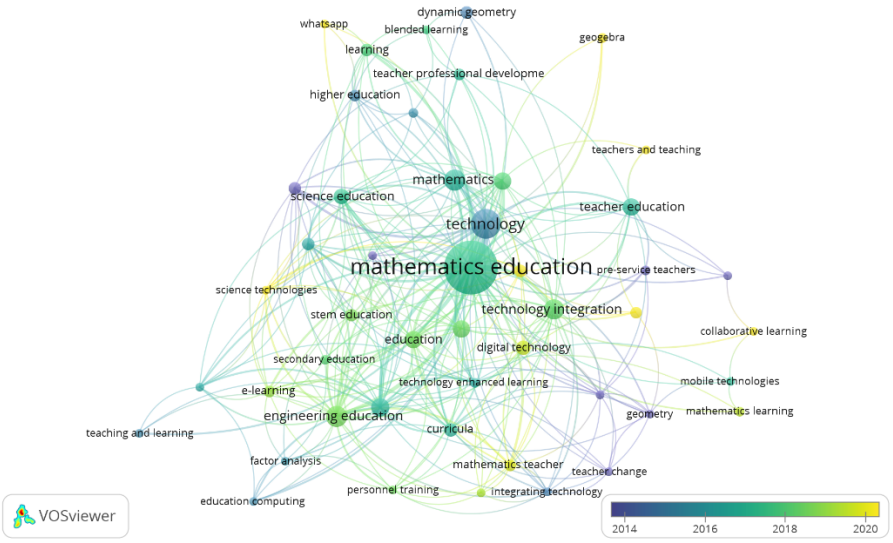

Figure 4. Overlay Visualization

Keywords in yellow are keywords used in 2020 and have not been widely used in previous research. As a result, keywords such as Whatsapp, Geogebra, Science Technologies, and Collaborative Learning offer the potential to become interesting and innovative research subjects related to Technology in Mathematics Education. Further research into the use of these keywords could provide new and valuable insights in advancing the field.

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3.2 Discussion

The development of education has encouraged the use of technology as a tool to improve the learning process [43], [44]. Thus, the integration of technology in education is becoming increasingly important because it provides opportunities to create more interactive, adaptive and effective learning experiences for students [45], [46]. Technology enables access to a wider range of learning resources and provides a platform for collaboration between students and teachers wherever they are. Therefore, increasing the use of technology in educational contexts is key to advancing the overall quality and accessibility of education.

The cluster entitled "Digital Technology Integration in Mathematics Education" includes a series of topics that focus on the integration of digital technologies in the context of mathematics education. These topics include curriculum development that integrates technology, education and digital technology, training of education personnel, changes in the instructional practices of mathematics teachers, and preparation of pre-service teachers to integrate technology in secondary mathematics instruction. The cluster aims to explore ways in which digital technologies can be effectively applied in mathematics learning, create learning environments that utilize digital tools to enhance students' mathematical understanding and skills, and support transformation in mathematics education towards a more integrated and effective use of technology [47], [48], [49].

The cluster entitled "Innovative Mathematics Education through Blended Learning" reflects a series of topics related to innovations in mathematics education through blended learning approaches. This cluster discusses the application of blended learning in the context of mathematics education, with a focus on the use of digital platforms such as WhatsApp as a communication and collaboration tool between students and teachers [50], [51]. Other topics included in this cluster include professional development of mathematics teachers, utilization of technology in dynamic geometry learning, and innovative efforts in improving the quality of mathematics learning at the higher education level. This cluster aims to explore the potential and challenges of integrating technology in mathematics education, with the hope of creating a learning environment that is dynamic, inclusive and enables students to develop a deep understanding of mathematics through diverse and innovative learning experiences.

The cluster entitled "Enhancing Mathematics Education through Educational Technology" covers a range of topics related to the use of technology in improving mathematics education. This cluster covers various aspects, including computer aided instruction, e-learning, application of technology in engineering education, factor analysis in educational contexts, and mathematics education at the secondary level. The main focus of this cluster is on strengthening the teaching and learning of mathematics through innovative and effective educational technology approaches [52], [53]. The cluster also includes research on the influence of technology on the teaching and learning process, as well as

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efforts to improve the quality of mathematics education by utilizing the maximum potential of technology. As such, this cluster aims to explore the role of technology in improving the accessibility, quality and effectiveness of mathematics education at different levels of education.

The cluster entitled "Interdisciplinary Approach to STEM Education Technology" describes a group of topics related to the use of technology in math and other science (STEM) education. This cluster summarizes various aspects, including science, technology, engineering and mathematics (STEM) education, the application of technology in science education, and the development of an integrated TPACK (Technological Pedagogical Content Knowledge) model. The main focus of this cluster is to explore how technology can be used effectively in supporting education across disciplines, enabling integration between different areas of knowledge and skills in rich and meaningful learning experiences [54]. The cluster also aims to encourage the development of technology-based learning models, facilitate the development of TPACK competencies for educators, and stimulate interdisciplinary collaboration in an effort to improve the overall quality of STEM education. As such, this cluster provides a foundation for exploration and innovation in the use of technology to enhance understanding and skills in science and math.

The cluster entitled "Enhancing Mathematics Learning through Collaborative Mobile Technologies" summarizes a series of topics related to the use of mobile-based technologies in enhancing collaborative mathematics learning. The cluster covers various aspects, including geometry learning, math problem solving, and technology-enhanced math learning. The main focus of this cluster is to strengthen mathematics learning through the use of mobile technologies that enable collaboration between students and facilitate problem-based learning [55]. By using mobile technology, the cluster aims to create a dynamic and responsive learning environment, allowing students to actively learn, interact with subject matter, and collaborate with their peers in solving mathematical problems. As such, this cluster provides a foundation for the development of innovative and inclusive learning approaches in the context of mathematics education supported by mobile technology.

The cluster entitled "Geogebra Integration in Teacher Professional Development for STEM Education" reflects a series of topics related to the use of Geogebra in teacher professional development for STEM education. The cluster covers aspects such as professional development, teacher education, and teacher beliefs in the context of using Geogebra, a software that supports mathematics learning through dynamic visual representations. The main focus of this cluster is to explore how Geogebra can be used as an effective tool in the professional development of mathematics teachers and STEM education as a whole. The cluster also aims to understand teachers' beliefs and perceptions towards using Geogebra in teaching and learning, as well as to investigate the impact of Geogebra integration in mathematics and STEM learning in general [56], [57]. By strengthening this

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understanding, the cluster seeks to support the development of more effective and innovative teaching practices in mathematics and STEM education, with the ultimate goal of improving the quality of learning and student achievement in these areas.

4. CONCLUSION

From the analysis conducted, it can be concluded that this study shows an interesting growth pattern in research on the use of technology in mathematics education over the period 1977 to 2024. This pattern changed significantly in the last 15 years, from 2009 to 2024, which is equivalent to four times the previous figure, or 66.13% of the total. The University of Pretoria dominated with the highest number of publications, at 14 articles. The source "Educational Studies in Mathematics" stands out as the best source with the highest h-index, at 5. Marien Alet Graham stands out as the author with the highest h-index, at 3. The paper Drijvers et al. (2010) stands out with the highest number of citations, at 168. There were 46 keywords divided into 6 groups, with the keywords Whatsapp, Geogebra, Science Technologies, and Collaborative Learning potentially being interesting and innovative research subjects related to Technology in Mathematics Education.

REFERENCES

[1] B. Blankenberger and A. M. Williams, "COVID and the impact on higher education: The essential role of integrity and accountability," *Adm. Theory Prax.*, vol. 42, no. 3, pp. 404–423, 2020.

[2] M. Chankseliani, I. Qoraboyev, and D. Gimranova, "Higher education contributing to local, national, and global development: new empirical and conceptual insights," *High. Educ.*, vol. 81, no. 1, pp. 109–127, 2021.

[3] G.-J. Hwang and S.-Y. Chien, "Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective," *Comput. Educ. Artif. Intell.*, vol. 3, p. 100082, 2022.

[4] D. McGunagle and L. Zizka, "Employability skills for 21st-century STEM students: the employers' perspective," *High. Educ. Ski. Work. Learn.*, vol. 10, no. 3, pp. 591–606, 2020.

[5] Z. K. Szabo, P. Körtesi, J. Guncaga, D. Szabo, and R. Neag, "Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills," *Sustainability*, vol. 12, no. 23, p. 10113, 2020.

[6] A. Fiala, "Critical Character Education: Whose Character? Which Virtues?," *Interchange*, pp. 1–21, 2024.

[7] M. S. Ramírez-Montoya, L. Quintero Gámez, J. Sanabria-Z, and M. Portuguez-Castro, "Exploring Complex Thinking in Latin American Universities: Comparative Analysis Between Programs and Alternative Credentials," *J. Latinos Educ.*, pp. 1–22, 2024.

[8] R. Jindal, "From Classroom to Career: A Holistic Approach to Student Preparedness," in *Preparing Students From the Academic World to Career Paths: A Comprehensive Guide*, IGI Global, 2024, pp. 232–245.

[9] E. Palmgren and T. Rasa, "Modelling Roles of Mathematics in Physics: Perspectives for Physics Education," *Sci. Educ.*, vol. 33, no. 2, pp. 365–382, 2024.

ISSN: 2620-4129
E-ISSN: 2621-3885

[10] A. Hoffmann and R. Even, "What do mathematicians wish to teach teachers about the discipline of mathematics?," *J. Math. Teach. Educ.*, pp. 1–19, 2023.
[11] S. Jablonski and M. Ludwig, "Teaching and Learning of Geometry—A Literature Review on Current Developments in Theory and Practice," *Educ. Sci.*, vol. 13, no. 7, p. 682, 2023.
[12] H. Jin, D. Cisterna, H. J. Shin, and M. Vonk, "Mathematization: A crosscutting theme to enhance the curricular coherence," in *Quantitative Reasoning in Mathematics and Science Education*, Springer, 2023, pp. 261–279.
[13] C. A. Rodríguez-Nieto, H. A. C. González, J. Arenas-Peñaloza, C. E. Schnorr, and V. F. Moll, "Onto-semiotic analysis of Colombian engineering students' mathematical connections to problems-solving on vectors: A contribution to the natural and exact sciences," *EURASIA J. Math. Sci. Technol. Educ.*, vol. 20, no. 5, p. em2438, 2024.
[14] D. Baran-Bulut and T. Yuksel, "Interdisciplinary Teaching: Solving Real-Life Physics Problems through Mathematical Modelling," *Electron. J. Res. Sci. Math. Educ.*, vol. 27, no. 4, pp. 118–140, 2024.
[15] A. Bakker, J. Cai, and L. Zenger, "Future themes of mathematics education research: An international survey before and during the pandemic," *Educ. Stud. Math.*, vol. 107, no. 1, pp. 1–24, 2021.
[16] C.-Y. Chang, C.-L. Yang, H.-J. Jen, H. Ogata, and G.-H. Hwang, "Facilitating nursing and health education by incorporating ChatGPT into learning designs," *Educ. Technol. Soc.*, vol. 27, no. 1, pp. 215–230, 2024.
[17] A. Adlina, E. Syahputra, and P. Sitompul, "The Effect of Mathematical Literacy Ability, Critical Thinking Ability, and Mathematical Communication Ability on the Mathematical Problem Solving Ability," in *Proceedings of the 5th International Conference on Science and Technology Applications, ICoSTA 2023, 2 November 2023, Medan, Indonesia*, 2024.
[18] H. Suryani, A. Setiani, and N. Agustiani, "Gamification of Mathematics Teaching Materials to Improve Problem Solving and Critical Thinking Ability: The Experts' Assessment," *Educ. Adm. Theory Pract.*, vol. 30, no. 4, pp. 819–833, 2024.
[19] Ü. Karabıyık, "Investigation of the Effect of Gamified Learning on Motivation and Success in Math Class," *J. Educ. Pract.*, vol. 8, no. 1, pp. 32–52, 2024.
[20] M. Dockendorff and F. G. Zaccarelli, "Successfully preparing future mathematics teachers for digital technology integration: a literature review," *Int. J. Math. Educ. Sci. Technol.*, pp. 1–32, 2024.
[21] M. A. Ayanwale, O. P. Adelana, and T. T. Odufuwa, "Exploring STEAM teachers' trust in AI-based educational technologies: A structural equation modelling approach," *Discov. Educ.*, vol. 3, no. 1, pp. 1–22, 2024.
[22] M. Basitere, E. Rzyankina, and P. Le Roux, "Reflection on experiences of first-year engineering students with blended flipped classroom online learning during the COVID-19 pandemic: A case study of the mathematics course in the extended curriculum program," *Sustainability*, vol. 15, no. 6, p. 5491, 2023.
[23] V. Shurygin, T. Anisimova, R. Orazbekova, and N. Pronkin, "Modern approaches to teaching future teachers of mathematics: the use of mobile applications and their impact on students' motivation and academic success in the context of STEM education," *Interact. Learn. Environ.*, pp. 1–15, 2023.
[24] T. Koparan, H. Dinar, E. T. Koparan, and Z. S. Haldan, "Integrating augmented reality into

mathematics teaching and learning and examining its effectiveness," *Think. Ski. Creat.*, vol. 47, p. 101245, 2023.
[25] S. Poçan, B. Altay, and C. Yaşaroğlu, "The effects of Mobile technology on learning performance and motivation in mathematics education," *Educ. Inf. Technol.*, vol. 28, no. 1, pp. 683–712, 2023.
[26] A. Almufarreh and M. Arshad, "Promising emerging technologies for teaching and learning: Recent developments and future challenges," *Sustainability*, vol. 15, no. 8, p. 6917, 2023.
[27] R. P. Bringula and F. A. L. Atienza, "Mobile computer-supported collaborative learning for mathematics: A scoping review," *Educ. Inf. Technol.*, vol. 28, no. 5, pp. 4893–4918, 2023.
[28] Z. Cui, O. Ng, and M. S.-Y. Jong, "Integration of computational thinking with mathematical problem-based learning," *Educ. Technol. Soc.*, vol. 26, no. 2, pp. 131–146, 2023.
[29] C. L. Chan, R. H. Shroff, W. K. Tsang, F. S. T. Ting, and R. C. C. Garcia, "Assessing the effects of a collaborative problem-based learning and peer assessment method on junior secondary students' learning approaches in mathematics using interactive online whiteboards during the COVID-19 pandemic," *Int. J. Mob. Learn. Organ.*, vol. 17, no. 1–2, pp. 6–31, 2023.
[30] E. S. Boye and D. D. Agyei, "Effectiveness of problem-based learning strategy in improving teaching and learning of mathematics for pre-service teachers in Ghana," *Soc. Sci. Humanit. Open*, vol. 7, no. 1, p. 100453, 2023.
[31] J. P. A. Ioannidis and Z. Maniadis, "Quantitative research assessment: using metrics against gamed metrics," *Intern. Emerg. Med.*, vol. 19, no. 1, pp. 39–47, 2024.
[32] C. Rostami, L. Nemati Anaraki, S. Asadzandi, and M. K. Saberi, "Bibliometric Analysis and Visualization of Scientific Publications of Iran University of Medical Sciences during 1980-2020," *Int. J. Inf. Sci. Manag.*, vol. 22, no. 1, pp. 223–240, 2024.
[33] P. Drijvers, M. Doorman, P. Boon, H. Reed, and K. Gravemeijer, "The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom," *Educ. Stud. Math.*, vol. 75, pp. 213–234, 2010.
[34] J. Roschelle *et al.*, "Integration of technology, curriculum, and professional development for advancing middle school mathematics: Three large-scale studies," *Am. Educ. Res. J.*, vol. 47, no. 4, pp. 833–878, 2010.
[35] A. Bray and B. Tangney, "Technology usage in mathematics education research–A systematic review of recent trends," *Comput. Educ.*, vol. 114, pp. 255–273, 2017.
[36] M.-H. Park, D. M. Dimitrov, L. G. Patterson, and D.-Y. Park, "Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics," *J. Early Child. Res.*, vol. 15, no. 3, pp. 275–291, 2017.
[37] I. Lee, S. Grover, F. Martin, S. Pillai, and J. Malyn-Smith, "Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering, and mathematics education," *J. Sci. Educ. Technol.*, vol. 29, pp. 1–8, 2020.
[38] J. M. Ritz and S.-C. Fan, "STEM and technology education: International state-of-the-art," *Int. J. Technol. Des. Educ.*, vol. 25, pp. 429–451, 2015.
[39] A. van Langen and H. Dekkers, "Cross-national differences in participating in tertiary science, technology, engineering and mathematics education," *Comp. Educ.*, vol. 41, no. 3, pp. 329–350, 2005.

[40] S. D. Craig *et al.*, "The impact of a technology-based mathematics after-school program using ALEKS on student's knowledge and behaviors," *Comput. Educ.*, vol. 68, pp. 495–504, 2013.
[41] Q. R. Alexander and M. A. Hermann, "African-American women's experiences in graduate science, technology, engineering, and mathematics education at a predominantly White university: a qualitative investigation.," *J. Divers. High. Educ.*, vol. 9, no. 4, p. 307, 2016.
[42] F. Reinhold, S. Hoch, B. Werner, J. Richter-Gebert, and K. Reiss, "Learning fractions with and without educational technology: What matters for high-achieving and low-achieving students?," *Learn. Instr.*, vol. 65, p. 101264, 2020.
[43] C. K. Y. Chan, "A comprehensive AI policy education framework for university teaching and learning," *Int. J. Educ. Technol. High. Educ.*, vol. 20, no. 1, p. 38, 2023.
[44] O. K. T. Kilag *et al.*, "ICT application in teaching and learning," *Sci. Educ.*, vol. 4, no. 2, pp. 854–865, 2023.
[45] S. Elbanna and L. Armstrong, "Exploring the integration of ChatGPT in education: adapting for the future," *Manag. Sustain. An Arab Rev.*, vol. 3, no. 1, pp. 16–29, 2024.
[46] D. Aggarwal, "Integration of innovative technological developments and AI with education for an adaptive learning pedagogy," *China Pet. Process. Petrochemical Technol.*, vol. 23, no. 2, 2023.
[47] D. Hillmayr, L. Ziernwald, F. Reinhold, S. I. Hofer, and K. M. Reiss, "The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis," *Comput. Educ.*, vol. 153, p. 103897, 2020.
[48] E. M. Mulenga and J. M. Marbán, "Is COVID-19 the gateway for digital learning in mathematics education?," *Contemp. Educ. Technol.*, vol. 12, no. 2, p. ep269, 2020.
[49] M. S. Alabdulaziz, "COVID-19 and the use of digital technology in mathematics education," *Educ. Inf. Technol.*, vol. 26, no. 6, pp. 7609–7633, 2021.
[50] J. Engelbrecht and G. Oates, "Student collaboration in blending digital technology in the learning of mathematics," in *Handbook of cognitive mathematics*, Springer, 2022, pp. 869–907.
[51] J. Naidoo and K. J. Kopung, "Technology for the 21 st Century: Exploring the Use of WhatsApp Instant Messaging for Pre-Service Teachers' Learning of Mathematics.," *Int. J. Technol. Math. Educ.*, vol. 27, no. 2, 2020.
[52] P. Yaniawati, R. Kariadinata, N. Sari, E. Pramiarsih, and M. Mariani, "Integration of e-learning for mathematics on resource-based learning: Increasing mathematical creative thinking and self-confidence," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 6, pp. 60–78, 2020.
[53] S. H. P. W. Gamage, J. R. Ayres, and M. B. Behrend, "A systematic review on trends in using Moodle for teaching and learning," *Int. J. STEM Educ.*, vol. 9, no. 1, p. 9, 2022.
[54] J. Zeng, S. Parks, and J. Shang, "To learn scientifically, effectively, and enjoyably: A review of educational games," *Hum. Behav. Emerg. Technol.*, vol. 2, no. 2, pp. 186–195, 2020.
[55] M. I. Zakaria, M. F. A. Hanid, and R. Hassan, "Combination of M-learning with Problem Based Learning: Teaching Activities for Mathematics Teachers.," *Int. J. Interact. Mob. Technol.*, vol. 17, no. 9, 2023.
[56] M. S. Uwurukundo, J. F. Maniraho, and M. Tusiime, "GeoGebra integration and effectiveness in the teaching and learning of mathematics in secondary schools: A review

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of literature," *African J. Educ. Stud. Math. Sci.*, vol. 16, no. 1, pp. 1–13, 2020.
[57] R. Ziatdinov and J. R. Valles Jr, "Synthesis of modeling, visualization, and programming in GeoGebra as an effective approach for teaching and learning STEM topics," *Mathematics*, vol. 10, no. 3, p. 398, 2022.

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