

## SYSTEMATIC LITERATURE REVIEW (SLR) OF TECHNOLOGY IN MATHEMATICS LEARNING DURING THE LAST DECADE

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### Abstract:

The use of technology in learning Mathematics in the current digital era is very important. However, knowledge about technology in Mathematics learning is still lacking for the majority of teaching staff. Therefore, it is important to conduct basic research regarding technology in teaching Mathematics. This research is a literature review that aims to review articles about Technology in Mathematics Learning which includes applications, software, platforms, and online course providers used in Mathematics learning. The articles reviewed are English-language articles published from 2013 to 2022 on the Springer database. The process of determining the articles analyzed in this study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principles. Based on the results of the analysis, it was obtained: 1) the highest distribution of article publications in 2022, namely 24 articles; 2) the most widely used technologies (applications, software, platforms and online course providers) are GeoGebra and Video (animated videos, learning videos, and video tutorials), Digital Games and Intelligent Tutoring Systems (ITS); 3) the most articles, namely articles with 3 authors, 23 articles; 4) that the countries with the most researchers conducting research on technology in teaching mathematics are the USA and UK with respective percentages of 35.06% and 12.99%; and 5) The publisher that publishes the most articles about technology in Mathematics learning is Digital Experiences in Mathematics Education. Researchers recommend conducting meta-analysis research on the impact of using technology on Mathematics learning.

**Keywords:** Technology, Mathematics Learning, Systematic Literature Review

## SYSTEMATIC LITERATURE REVIEW (SLR) TEKNOLOGI DALAM PEMBELAJARAN MATEMATIKA SELAMA DEKADE TERAKHIR

### Abstrak:

Penggunaan teknologi dalam pembelajaran Matematika di era digital saat ini sangatlah penting. Namun, pengetahuan tentang teknologi dalam pembelajaran Matematika masih kurang bagi mayoritas staf pengajar. Oleh karena itu, penting untuk melakukan penelitian dasar mengenai teknologi dalam pengajaran Matematika. Penelitian ini merupakan kajian pustaka yang bertujuan untuk mengkaji artikel tentang Teknologi dalam Pembelajaran Matematika yang meliputi aplikasi,

perangkat lunak, platform, dan penyedia mata kuliah online yang digunakan dalam pembelajaran Matematika. Artikel yang diulas adalah artikel berbahasa Inggris yang diterbitkan dari 2013 hingga 2022 di database Springer. Proses penentuan artikel yang dianalisis dalam penelitian ini menggunakan prinsip Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Berdasarkan hasil analisis diperoleh 1) sebaran publikasi artikel tertinggi tahun 2022 yaitu 24 artikel; 2) teknologi yang paling banyak digunakan (aplikasi, perangkat lunak, platform, dan penyedia kursus online) adalah GeoGebra dan Video (video animasi, video pembelajaran, dan tutorial video), Game Digital dan Sistem Bimbingan Belajar Cerdas (ITS); 3) artikel terbanyak, yaitu artikel dengan 3 penulis, 23 artikel; 4) bahwa negara-negara dengan peneliti terbanyak yang melakukan penelitian tentang teknologi dalam pengajaran matematika adalah Amerika Serikat dan Inggris dengan persentase masing-masing 35,06% dan 12,99%; dan 5) Penerbit yang paling banyak menerbitkan artikel tentang teknologi dalam pembelajaran Matematika adalah Pengalaman Digital dalam Pendidikan Matematika. Peneliti merekomendasikan untuk melakukan penelitian meta-analisis tentang dampak penggunaan teknologi pada pembelajaran Matematika.

**Kata Kunci:** Teknologi, Pembelajaran Matematika, Kajian Pustaka Sistematis

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## INTRODUCTION

Developing students' understanding of Science, Technology, Engineering, and Mathematics (STEM) concepts in the learning process is an educational priority in many countries today (Fowler, Cutting, Kennedy, Leonard, Gabriel, & Jaeschke, 2021). However, until now, problems in learning Mathematics itself are things that cannot be resolved. The problem that is often faced by teachers when teaching Mathematics is the low motivation and interest of students in learning Mathematics. So it has an impact on the low results of student mathematics learning. To increase students' motivation, interest, and learning outcomes in Mathematics, one way to do this is to take advantage of technological developments (Xu & Ouyang, 2022).

The use of technology in mathematics learning has become increasingly widespread since the Covid-19 pandemic (Alabdulaziz, 2021; Del Olmo-Munoz, Gonzalez-Calero, Diago, Arnau, & Arevalillo-Herraez, 2022). The

Covid-19 pandemic requires learning to be carried out online, including in Indonesia. Online learning requires educators and researchers to be more innovative in developing teaching materials and utilizing technological developments in learning (Larison, Richards, & Sherin, 2022; Nurviani & Abdullah, 2022). In Mathematics learning itself, many have used technology in the learning process before the Covid-19 pandemic occurred, such as the use of digital games (Benning, Linsell, & Ingram, 2018; Chinnappan & Thomas, 2000; Moore-Russo, Diletti, Strzelec, Reeb, Schillace, Martin, Scanlon, 2015; Sudarsana, Nakayanti, Sapta, Haimah, Satria, Saddhono, Mursalin, 2019). The use of Grid Algebra (Hewitt, 2016), the use of Google Sketch Up (Panorkou & Pratt, 2016), and the use of Graphing Calculator (Roorda, Vos, Drijvers, & Goedhart, 2016).

Learning Mathematics cannot be separated from the development and use of technology (Kurniati & Ramly, 2022). The use of technology can help and facilitate students in understanding concepts in Mathematics (Jupri, Drijvers, & Van den Heuvel-Panhuizen, 2015) and can improve their ability to solve mathematical problems (Sokolowski, Li, & Willson, 2015). Existing technology can increase motivation (Chao, Chen, Star, & Dede, 2016), interest (Tepla, Teply, & Smejkal, 2022), and student learning outcomes in Mathematics (Wang, Chen, Hwang, Guan, & Wang, 2022). So, it can be concluded that technology has an important role in the learning process of Mathematics.

The use and development of technology in mathematics learning has been widely researched by experts such as (Moore-Russo, Diletti, Strzelec, Reeb, Schillace, Martin, Scanlon, 2015) researched the use of the Angry Bird digital game in Mathematics learning (Chao, Chen, Star, & Dede, 2016), examined digital resources on students' motivation and engagement in learning Mathematics, (Clark-Wilson, Robutti, & Thomas, 2020) researching the use of digital technology in mathematics learning, (Wang, Chen, Hwang, Guan, & Wang, 2022) researching the effect of digital games on students' mathematics learning outcomes, and (Tepla, Teply, & Smejkal, 2022) examined the effect of 3D models and animations on students' motivation and learning outcomes in Mathematics.

Based on the results of research conducted by the experts above, it can be interpreted that the use of technology in learning mathematics has a positive impact on learning outcomes, student activities, and students' higher-order thinking skills (HOTS). Therefore, it is important to know the technology

used in Mathematics learning through a literature review of articles related to technology in Mathematics learning. The research in the form of a literature review was conducted by Gamage, Ayres, and Behrend (2022), on 155 articles regarding the use of technology (Moodle) in learning Mathematics on the Scopus and Web of Science (Wos) databases. The results showed that the use of Moodle had a positive impact on learning. Furthermore, in a meta-analysis study conducted by Wang, Chen, Hwang, Guan, and Wang (2022) for 33 articles, it was found that digital games can improve student achievement.

Therefore, this study examines more about the types of technology that can be used in learning Mathematics on the Springer database. The questions in this research are as follows: (1) How is the distribution of articles about technology in Mathematics learning from 2013 to 2022? (2) What types of technology are used in articles about technology in Mathematics learning from 2013 to 2022? (3) How many authors in each article about technology in Mathematics learning from 2013 to 2022? (4) Which countries do the most research about technology in Mathematics learning from 2013 to 2022? (5) What is the publisher of articles about technology in Mathematics learning from 2013 to 2022?

## **METHODS**

The method used in this research is the literature review method. A literature review is a research method and process that is carried out by identifying, critically assessing, collecting, and analyzing data from relevant research to gather empirical evidence to answer certain research questions or hypotheses (Snyder, 2019). This research uses a systematic review protocol, namely the PRISMA process, which consists of the following 4 steps: (1) Identification of articles relevant to this research, (2) Screening using criteria determined by the author, (3) Classification of the filtered articles methodically using themes as determined by the author, and (4) determine the articles to be included in this review (Gamage, Ayres, & Behrend, 2022).

In this study, the authors searched for articles about Technology in Mathematics Learning in the Springer database (<https://link.springer.com>) which were published during the last 10 years, from 2013 to 2022. Researchers chose the Springer database because it is a reputable database that contains many research articles in the field of education. The article search was conducted on January 9–21, 2023. The research variables to be studied were the

distribution of annual publications, the type of technology, the number of authors, the most productive countries in research, and the publisher.

The articles referred to in this study are articles that discuss technology in learning Mathematics which includes: applications, software, platforms, and online course providers that can be used in the process of learning Mathematics. The articles reviewed were English articles published from 2013 to 2022. The process of determining the articles analyzed in this study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) principles (Xu & Ouyang, 2022). The process of determining the articles to be analyzed in this study can be seen in figure 1.

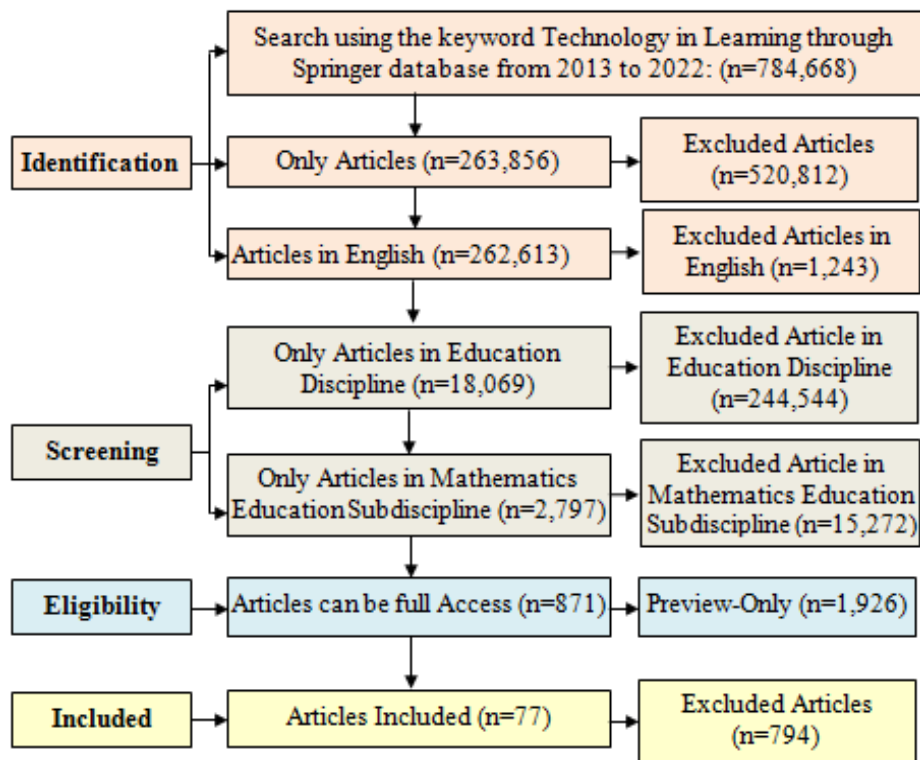


Figure 1. PRISMA Flow Diagram of Literature Review

The keywords used to obtain the articles analyzed in this study are Technology in learning. The technology in question is in the form of applications, software, platforms, or online course providers used in learning Mathematics. Articles must be in English and published from 2013 to 2022. Furthermore, articles are filtered based on educational disciplines and sub-disciplines of Mathematics education, all of which can be accessed. 871 articles were obtained which were then thoroughly examined full text of all articles.

To obtain articles that were analyzed to answer research questions as many as 77 articles.

Variables used in the analysis of the literature review to answer this research question include: (1) The distribution of annual publications; (2) The type of technology (applications, software, platforms, or online course providers); (3) Number of authors; (4) The most productive countries in research; and (4) The article publisher.

## RESULTS AND DISCUSSION

Specifically, this section presents the results of the analysis of selected articles in Springer databases from 2013 to 2022. The selected articles are articles in English that discuss Technology in Mathematics Learning and can be fully accessed. The results presented include the distribution of annual publications, the types of technology (applications, software, platforms, or online course providers), the number of authors, the most productive countries in research, and the publisher.

### 1. Distribution of Annual Publication

The annual publication distribution of articles from 2013 to 2022 can be seen in figure 2.

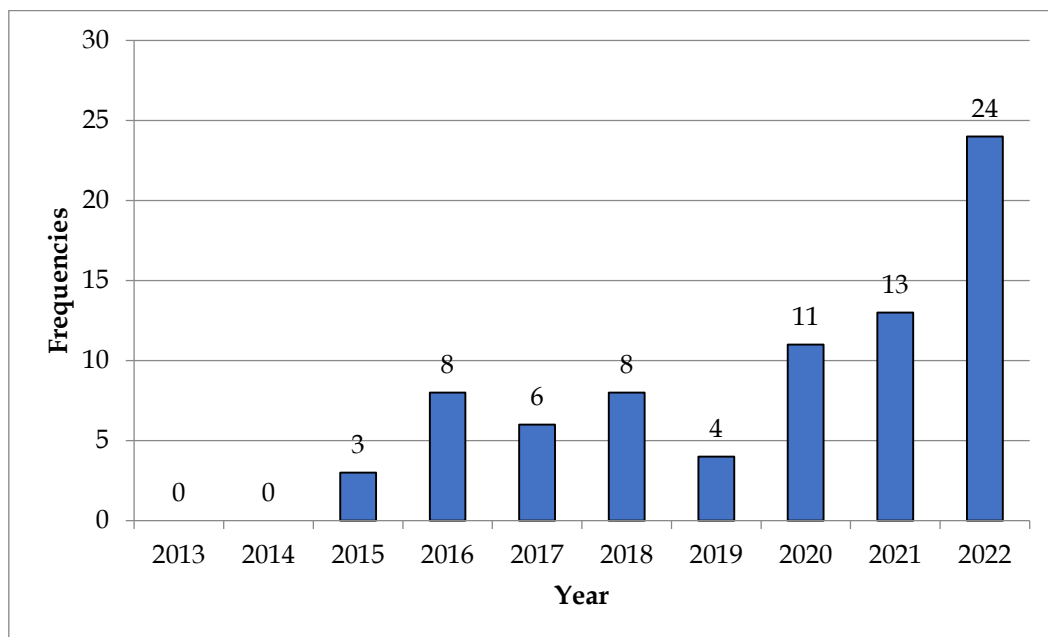


Figure 2. Distribution of Annual Publication

Based on figure 2, it can be seen that the number of articles published over the last 10 years has fluctuated, but over the last 3 years it has increased. In 2013 and 2014 no articles were published. In 2015 there were 3 articles, in 2016 there were 8 articles, in 2017 there were 6 articles, in 2018 there were 8 articles, in 2019 there were 4 articles, in 2020 there were 11 articles, in 2021 there were 13 articles, and in 2022 there were 24 articles.

## 2. Type of Technology in Mathematics Learning

The types of technology used in mathematics learning based on the results of the literature review on the selected articles can be seen in Table 1 and table 2.

Table 1. Technology in Mathematics Learning

No	Technology	Link Address
1	3D Models and Animations	-
2	AlgebraKit	<a href="https://algebrakit.com/">https://algebrakit.com/</a>
3	ASSISTments	<a href="https://new.assistments.org/">https://new.assistments.org/</a>
4	Cabri3D	<a href="https://cabri.com/en/instructor/cabri-3d/index.html">https://cabri.com/en/instructor/cabri-3d/index.html</a>
5	CAD Software	<a href="https://www.autodesk.com/solutions/cad-software">https://www.autodesk.com/solutions/cad-software</a>
6	Corinth	<a href="https://www.corinth3d.com/">https://www.corinth3d.com/</a>
7	Desmos	<a href="https://www.desmos.com/">https://www.desmos.com/</a>
8	Digital Game	-
9	Digital Game (Angry Birds)	<a href="https://www.angrybirds.com/">https://www.angrybirds.com/</a>
10	Digital Game (Expedition Atlantis)	
11	Digital Math Environment (DME)	<a href="https://www.dwo.nl/site/index_en.html">https://www.dwo.nl/site/index_en.html</a>
12	Fathom	<a href="https://fathom.concord.org/">https://fathom.concord.org/</a>
13	Fractions Lab	<a href="http://it21.dcs.bbk.ac.uk/italk2learn/">http://it21.dcs.bbk.ac.uk/italk2learn/</a>
14	GeoGebra	<a href="https://www.geogebra.org/">https://www.geogebra.org/</a>
15	Google SketchUp	<a href="https://www.sketchup.com/">https://www.sketchup.com/</a>
16	Graasp	<a href="https://graasp.eu/">https://graasp.eu/</a>
17	Grid Algebra	<a href="https://gridalgebra.com/welcome">https://gridalgebra.com/welcome</a>
18	Immersive Virtual Reality	-
19	Intelligent Tutoring	-

Systems (ITS)		
20	Jupyter Notebook	<a href="https://jupyter.org/">https://jupyter.org/</a>
11	LEAN Prover	<a href="https://leanprover.github.io/">https://leanprover.github.io/</a>
12	Learning Assistant Alliance	<a href="https://www.learningassistantalliance.org/">https://www.learningassistantalliance.org/</a>
13	LEGO Mindstorms EV3	-
14	MaLT2	-
15	MathCad	<a href="https://www.mathcad.com/en/">https://www.mathcad.com/en/</a>
16	Mathematical Internet Memes	-
17	MathTrack Project	<a href="https://projectmathtrack.wixsite.com/projectmathtrack">https://projectmathtrack.wixsite.com/projectmathtrack</a>
18	mBots	<a href="https://www.makeblock.com/steam-kits/mbot">https://www.makeblock.com/steam-kits/mbot</a>
19	Microworlds	<a href="http://www.microworlds.com/">http://www.microworlds.com/</a>
20	Moodle	<a href="https://moodle.org/">https://moodle.org/</a>
21	NE STEM 4U	<a href="https://www.unomaha.edu/academic-affairs/ne-stem-for-u/index.php">https://www.unomaha.edu/academic-affairs/ne-stem-for-u/index.php</a>
22	Padlet	<a href="https://padlet.com/">https://padlet.com/</a>

Table 2. Technology in Mathematics Learning (Continued)

No	Technology	Link Address
1	PMTs Courses	<a href="https://www.pmtcourses.com/">https://www.pmtcourses.com/</a>
2	Python	<a href="https://www.python.org/">https://www.python.org/</a>
3	RALS: Robot-Assisted Laparoscopic Surgery	-
4	Scratch	<a href="https://scratch.mit.edu/">https://scratch.mit.edu/</a>
5	SimCalc MathWorlds	<a href="http://kaputcenter.org/products/software/simcalc-mathworlds-software/">http://kaputcenter.org/products/software/simcalc-mathworlds-software/</a>
6	Socrative	<a href="http://www.socrative.com">www.socrative.com</a>
7	Tinker CAD	<a href="https://www.tinkercad.com/">https://www.tinkercad.com/</a>
8	Tinker Plots	<a href="https://www.tinkerplots.com/">https://www.tinkerplots.com/</a>
9	Video	-
10	Virtual Manipulatives	<a href="https://mathigon.org/polypad">https://mathigon.org/polypad</a> <a href="https://toytheater.com/category/teacher-tools/virtual-manipulatives/">https://toytheater.com/category/teacher-tools/virtual-manipulatives/</a>
11	Web-based Learning	-
12	WiiGraph	-



The type of technology most used in Mathematics learning from 2013 to 2022 can be seen in figure 3.

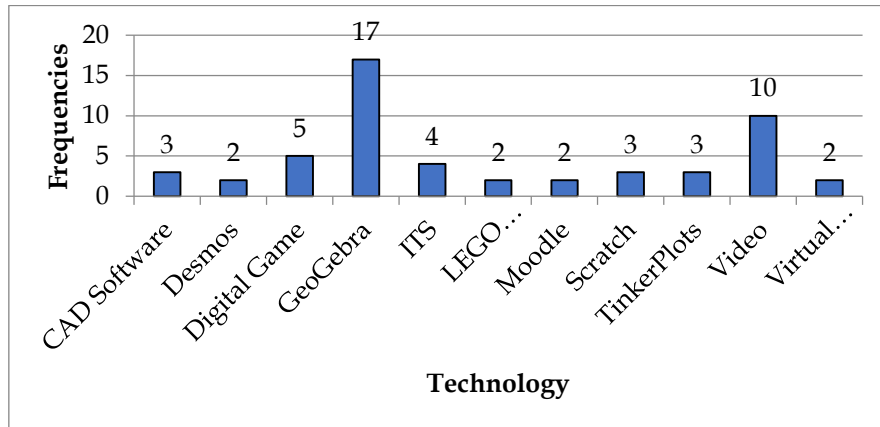


Figure 3. The Most Used of Technology in Mathematics Learning

Based on figure 3, it can be seen that the most widely used technologies (applications, software, platforms, and online course providers) are GeoGebra and Video (animated videos, learning videos, and video tutorials). Furthermore, the most widely used are Digital Games and Intelligent Tutoring Systems (ITS).

### 3. Number of Authors

The distribution of authors in the article about technology in Mathematics learning can be seen in figure 4.

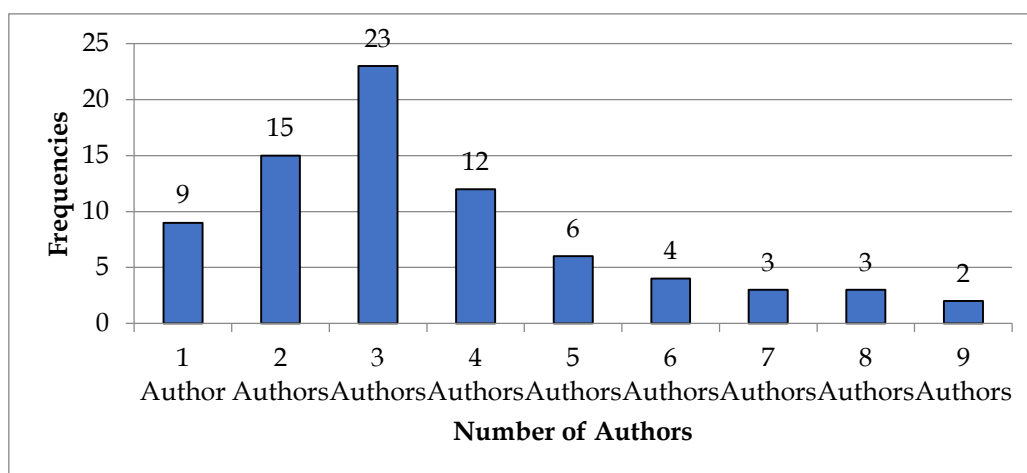


Figure 4. Number of Authors in Article about Technology in Mathematics Learning

Based on figure 4, it can be seen that the number of articles with a single author is 9 articles, articles with 2 authors are 15 articles, articles with 3 authors are 23 articles, articles with 4 authors are 12 articles, articles with 5 authors are 6 articles, articles with 6 authors as many as 4 articles, articles with 7 authors as many as 3 articles, articles with 8 authors as many as 3 articles, and articles with 9 authors as many as 2 articles.

#### 4. Most Productive Countries in Research

The most productive countries in research about technology in Mathematics learning from 2013 to 2022 can be seen in table 3.

Table 3. The Most Productive Countries in Research

Country	N of Articles	%
USA	27	35.06
UK	10	12.99
Australia	6	7.79
Germany	6	7.79
The Netherlands	5	6.49
Sweden	4	5.19
China	3	3.90
Italy	3	3.90
Canada	2	2.60
Finland	2	2.60
Norway	2	2.60
Colombia	1	1.30
Czech Republic	1	1.30
France	1	1.30
Hong Kong	1	1.30
Israel	1	1.30
Mexico	1	1.30
Spain	1	1.30

Based on table 3, it can be seen that the countries with the most researchers researching technology in Mathematics learning are the USA and UK with respective percentages of 35.06% and 12.99%. Furthermore, Australia and Germany with the same percentage, namely 7.79%. The Netherlands and Sweden with respective percentages of 6.49% and 5.19%. China and Italy with the same percentage, namely 3.90%. Canada, Finland, and Norway with the

same percentage, namely 2.60%. Colombia, Czech Republic, France, Hong Kong, Israel, Mexico and Spain with the same percentage, namely 1.30%.

## 5. The Article Publisher

The article published about technology in Mathematics learning from 2013 to 2022 can be seen in table 4.

Table 4. The Article Publisher

<b>Publisher</b>	<b>Nof Articles</b>	<b>%</b>
Digital Experiences in Mathematics Education	25	32.47
International Journal of STEM Education	21	27.27
Educational Studies in Mathematics	11	14.29
ZDM Mathematics Education	7	9.09
International Journal of Science and Mathematics Education	4	5.19
Journal of Mathematics Teacher Education	3	3.90
International Journal of Research in Undergraduate Mathematics Education	2	2.60
Mathematics Education Research Journal	2	2.60
Canadian Journal of Science, Mathematics and Technology Education	2	2.60

Based on table 4, it can be seen that publishers who publish articles about technology in Mathematics learning are Digital Experiences in Mathematics Education with a percentage of 32.47%. Furthermore, the International Journal of STEM Education with a percentage of 27.27%, Educational Studies in Mathematics with a percentage of 14.29%, ZDM Mathematics Education with a percentage of 9.09%, International Journal of Science and Mathematics Education with a percentage of 5.19%, Journal of Mathematics Teacher Education with a percentage of 3.90%, International Journal of Research in Undergraduate Mathematics Education, Mathematics Education Research Journal, and Canadian Journal of Science, Mathematics and Technology Education with the same percentage, namely 2.60%.

This research is literature review research on technology (applications, software, platforms, and online course providers) in learning Mathematics from 2013 to 2022. This research will be useful for researchers and educators to find out and learn more about the use of technology in learning Mathematics.

This is because learning Mathematics cannot be separated from the development and use of technology which is increasingly rapid. Since the covid-19 pandemic occurred, education at all levels in Indonesia must be carried out online, thus encouraging researchers and educators to innovate in implementing learning, especially in learning Mathematics. One strategy that can be done is to use technology. Therefore, a lot of research has been conducted regarding the use of technology in learning mathematics in the last three years. Research conducted by Gamage, Ayres, and Behrend. (2022), analyzed 155 articles in the Scopus and Web of Science (WoS) database from January 2015 to June 2021 regarding the trend of using one of the technologies (Moodle) in learning Mathematics, the result was that the number of publications from year to year increased. This proves that research and publications regarding the use of technology in learning mathematics continue to increase.

Based on the results of the analysis of selected articles (77 articles) it is known that a lot of research has been done on the use of technology in learning Mathematics. 2022 is the year with the most published articles about technology in Mathematics learning. From 2015 to 2019 the publication of articles on technology in mathematics learning experienced fluctuations, while from 2020 to 2022 it continued to increase rapidly. This is due to the increasingly rapid development of technology and the increasingly widespread use of technology in online learning. In addition, this was also caused by the Covid-19 pandemic which encouraged the implementation of online learning (Drijvers, Thurm, Vandervieren, Klinger, Moons, Van der Ree, Doorman, 2021).

Furthermore, it is known that the most widely used technology in learning Mathematics is GeoGebra. GeoGebra is a Mathematics application/software that can be used online or offline. GeoGebra is specifically used in Geometry material, both Plane Geometry (2D) and Space Geometry (3D). The use of GeoGebra in learning Mathematics is expected to increase students' interest, motivation, and learning outcomes in Mathematics, both in distance learning and face-to-face learning. As in research conducted by Nurwijaya (2019), the use of GeoGebra can improve students' learning outcomes and completeness in mathematics learning. Furthermore, research conducted by Hergenbahn and Olson (2015) shows that the use of GeoGebra can increase students' creativity and problem-solving abilities.

Furthermore, articles with 3 authors were the most published articles in the last 10 years, namely 29.87% of articles, with authors with 2 authors being the second largest with 19.48% of articles. Authors with 4 authors are the third largest with 15.58% of articles, and authors with a single author are the fourth largest with 11.69% of articles. While the number of authors with 5 or more authors amounted to 23.38% of the articles. It can be concluded that research on technology in mathematics learning is mostly researched by 1-4 authors. This proves that researchers with technology topics in Mathematics learning like to do research both individually and in groups.

The United States (USA) is the country with the highest number of publications regarding technology in Mathematics learning in the Springer database, namely 35.06%. The large number of publications from the USA may be related to the high budget for research and development (Irwanto, 2021). Based on data on scimagojr.com, the USA is the country with the highest ranking in article publications with reputable publishers. Furthermore, the United Kingdom (UK) is the country with the second largest number of publications, namely 12,99%. Based on data on scimagojr.com, the UK is the third-ranked country in article publication in reputable publishers after China.

Digital Experiences in Mathematics Education and the International Journal of STEM Education are publishers that publish the most technology research articles in Mathematics learning with consecutive article numbers of 32.47% and 27.27%. Both publishers are leading international publishers. In third place is the Study of Mathematics Education as much as 14.29%. Overall there are 9 publishers in the Springer database that publish articles about technology in mathematics learning. This shows that several reputable publishers focus on learning technology issues, especially learning Mathematics (Gamage, Ayres, & Behrend, 2022).

Furthermore, this study provides information about technology that can be used in learning Mathematics accompanied by a link addressing the technology in question. Existing technology is expected to increase students' interest, motivation, and learning outcomes in Mathematics. The use of technology can improve the learning environment to make the learning process more interactive and student-centered (Fowler, Cutting, Kennedy, Leonard, Gabriel, & Jaeschke, 2021). During the learning process, students can explore enthusiastically using existing technology (Clark-Wilson, Robutti, & Thomas, 2020). Furthermore, it is hoped that research can be carried out on the

effect of using technology on students' higher-order thinking skills and mathematical problem-solving abilities.

## CONCLUSION

Based on the selected articles that were analyzed, it was found that research on technology in mathematics learning has been carried out a lot during the last 10 years. Research trends fluctuate every year and for the last three years have experienced a significant increase. Based on the results of the analysis, it was found that the most widely used technologies in learning Mathematics from 2013 to 2022 were GeoGebra, Videos (animated videos, learning videos, and video tutorials), Digital Games, and Intelligent Tutoring Systems (ITS). Furthermore, it is known that articles with 3 authors are the most published article, namely 23 articles, then articles with 2 authors, namely 15 articles. The USA is the country with the most researchers researching technology in mathematics learning, namely 27 research articles, followed by the UK with 10 research articles. Digital Experiences in Mathematics Education is the publisher that publishes the most articles about technology in Mathematics learning, with 25 articles, followed by the International Journal of STEM Education with 21 articles.

## LIMITATIONS AND RECOMMENDATIONS

This research is limited only to the type of technology used in learning Mathematics. Recommendations for further research to utilize technology in learning Mathematics and conduct a meta-analysis to examine its impact on students' interest, motivation, learning outcomes, and higher-order thinking skills in Mathematics.

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