

RESEARCH TRENDS IN THE USE OF DIGITAL TOOLS IN SCHOOL MATHEMATICS EDUCATION: A SYSTEMATIC REVIEW OF SCOPUS-INDEXED STUDIES (2012-2025)

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Abstract. The use of digital tools is becoming increasingly prevalent in mathematics education across different levels of education. In this study, a systematic review is conducted with 23 articles published between 2012 and 2025, indexed in the Scopus database, and based on the PRISMA criteria, to explore research trends in the use of digital tools in mathematics teaching in schools. Results highlight a considerable increase in the volume of publications after 2021; the main contexts including Europe and Asia; lower and upper secondary education, focusing on the use of dynamic mathematics software, augmented reality, and programming as digital tools, with a shift from visualization to modeling and computation at higher education levels. Research findings imply a change in the pedagogical approach to using technology, from an auxiliary to a cognitive partner in deepening conceptual knowledge and critical thinking. However, several limitations exist, such as small sample sizes, short-term interventions, a lack of comparison between different digital tools, and limited consideration of teachers' technological expertise.

Keywords: Digital tools, Systematic review, Mathematics education, Scopus.

1. Introduction

Mathematics is an essential discipline that plays a significant role across numerous fields of science and everyday life. In the present-day educational process, teachers have to organize instruction to facilitate the development of students' sustainable problem-solving skills (Aktayeva et al., 2022, p3309-3310). The integration of technology in mathematics instruction has greatly increased the efficiency of knowledge acquisition. According to Trinh et al. (2023, p3), the digital transformation of the education process refers to the application of digital technologies across different parts of the education process, thereby creating innovations in methods of instruction and knowledge assessment to ensure increased access to and acquisition of knowledge by students. In the field of mathematics teaching, digital technologies serve as a means of delivering information and cognitive tools that help learners understand complex concepts and engage in interactive learning (Klochko et al., 2024, p57-58). Therefore, technology can play various roles in mathematics teaching.

Extensive research has demonstrated that the integration of digital technology in mathematics education positively impacts students' motivation and engagement (Ariyanto et al., 2023, p1704-1706), as well as their performance. It helps students understand concepts more effectively through visualization and interaction, which are often difficult to achieve with traditional instructional methods (Doorman et al., 2012). Also, it allows for personalizing the learning process to meet students' different needs and delivering the required support promptly (Mollakuqe & Mollakuqe, 2025). Internet resources allow students to become actively involved in the process of learning mathematics through an inquiry-based learning approach. Moreover, it enables automated and adaptive assessment of students' work, thereby saving teachers' time and providing prompt feedback to students (Huang et al., 2023, p28). The digitalization of homework assignments is believed to lead to the development of

more engaging and effective learning tasks and, hence, to the partial improvement of the quality of mathematics education. In recent years, the use of AI-based technologies and platforms has increased opportunities for implementing formative assessment and developing students' self-directed learning abilities and metacognitive skills (Pham et al., 2025).

Earlier reviews have highlighted the growing importance of digital technologies in mathematics education and their ability to improve students' conceptual understanding, mathematical reasoning, and engagement (Mollakuqe & Mollakuqe, 2025, p1083). At the same time, systematic review methods, as represented by PRISMA 2020, emphasize the importance of evidence synthesis and transparency (Page et al., 2021). Nonetheless, the existing literature on the use of digital technology in mathematics education remains unsystematic (Pittalis et al., 2025, p1083). In particular, there is a lack of research on identifying development trends, the methodology for using digital technology, and the scale of its application in the context of school mathematics education. Also, there is insufficient empirical evidence on the impact of digitalization on students' learning outcomes, namely the development of concepts and critical thinking (Pham et al., 2025). Another gap concerns the digital divide, where students' socio-economic status and readiness to work with digital tools should be examined (Mollakuqe & Mollakuqe, 2025). The need for pedagogical innovations through the efficient use of digital technologies also warrants research into instructional techniques, innovative assessment methods, personalized learning, and interdisciplinary approaches in mathematics education (Mollakuqe & Mollakuqe, 2025).

To address these gaps, the current study aims to answer the following research questions: (RQ1): *What are the trends and features of research on the use of digital tools in school mathematics education?* (RQ2): *What digital tools and technologies have been used to assist mathematics education in schools?* (RQ3): *What impacts of digital technology on school mathematics education have been reported and what are the limitations of the research on this topic?* The findings will provide the theoretical basis for an overview of digital transformation in mathematics education worldwide in K-12 settings.

2. Methodology

In the context of evidence-based education, systematic reviews are increasingly utilized as a robust methodological approach to synthesize and analyze existing literature, thereby providing a scientific basis for policy planning, teacher professional development, and further research orientation (Cohen et al., 2018). This study applies the systematic review method to analyze the bibliographic characteristics, research context, and methodologies of studies on the use of digital technology in K-12 mathematics education.

Before collecting data, the research team discussed and agreed on the search strategy, keywords, and selection criteria to ensure relevance to the research objectives. The entire research process adhered to PRISMA guidelines, encompassing five key stages: defining the research question, searching literature, filtering and coding data, statistical analysis, and synthesizing results (Figure 1). Adopting PRISMA ensured systematicity, transparency, and reproducibility throughout the research (Page et al., 2021, p178).

2.1. Data Collection

Data were extracted from the Scopus database, using a search strategy that combined keywords related to digital technologies and mathematics education, and logical operators. Scopus was selected as the database because it is popular, reliable, and, most importantly, suitable for the research account of an educational institution in Vietnam. The search was limited, focusing on research related to the use of digital technology and those related to education and mathematics education in K-12 using the following keyword strings such as ("mathematics education" OR

"learning mathematics" OR "teaching mathematics") AND ("digital tool" OR "digital technology") AND ("high school" OR "K12" OR "Primary school" OR "Secondary school" OR "Middle school" OR "General Education"); AND (LIMIT-TO LANGUAGE, "English") AND (LIMIT-TO SUBJAREA, "MATH").

The researchers established selection and exclusion criteria as detailed in Table 1. The publications were selected based on the following criteria: (i) publications in English, excluding conference proceedings and book chapters or publications in other languages to ensure high quality and reliability as well as publication popularity; (ii) explicit mention of teaching or learning plans related to the use of technology in mathematics education.

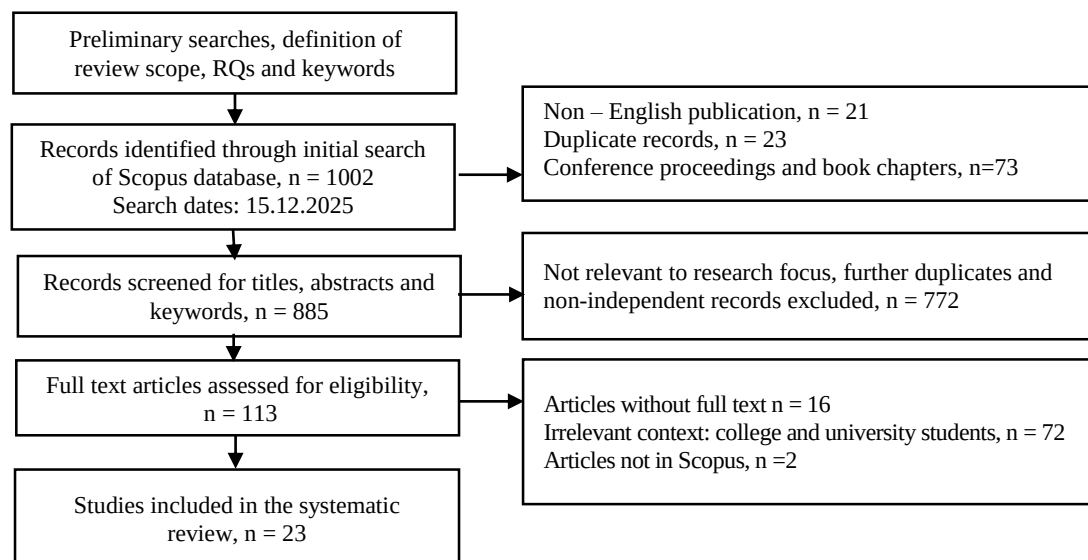


Figure 1. PRISMA process flowchart of the study

2.2. Data Screening

The document screening process was carried out according to PRISMA, which included the following steps:

Step 1 – Initial search using suggested keywords yielded 1,002 publications in the Scopus database; the researchers proceeded to screen for duplicate titles, abstracts, and keywords; eliminating proceedings and book chapters. The number of publications retained at this step was 885.

Step 2 – Read and screen the titles, abstracts, and keywords of the 885 documents, excluding those that do not meet the selection criteria above. This resulted in 113 publications selected for full-text review.

Step 3 – Search for and download the full text of the 113 publications using DOIs via sources such as Scopus, ResearchGate, and Google Scholar. Excluding publications with restricted access (where full text download was not possible) left a final sample of 97 publications.

Step 4 – The 97 publications were assigned to team members for full-text cross-reading and comparative evaluation, with any discrepancies resolved through joint discussion. In addition to basic metadata (author, publication year, citation index), other information was coded, including: (1) Educational level (Primary, Lower Secondary, Upper Secondary); (2) Research topic (e.g., digital technology in Geometry, Algebra, Calculus); (3) Research method (qualitative, quantitative, developmental research); and (4) Digital tools (GeoGebra, AI, AR, VR). Excluding articles that failed to meet the selection criteria (see Table 1) resulted in a final sample of 23 publications. These peer-reviewed journal articles feature explicitly detailed research methods and sufficient empirical evidence. A detailed summary of the 23

reviewed studies is provided in the link: https://docs.google.com/document/d/1retLI-cJOmsJkdik_VKgdFjuz3DGVaQd8aNEaQqylFw/edit?tab=t.0.

Table 1. Inclusion and exclusion criteria used in the study

Criteria	Selection	Exclusions
Content Scope	Studies focusing directly on digital transformation or incorporating educational technology into math instruction, where technology plays a pivotal role in pedagogical practice, student learning, or evaluation	Studies addressing educational technology in general, university mathematics education; teacher training; STEM/STEAM research that does not specifically analyze or clarify the context of mathematics education.
Research Subjects	Studies conducted with primary, lower secondary, or upper secondary students in formal school settings, where technology's pedagogical or cognitive role is explicitly analyzed.	Studies focusing on non-K12 or informal settings; and studies where technology is strictly used for basic tasks
Research Type	Experimental, semi-experimental, qualitative studies with clear pedagogical analysis, mixed-methods, or systematic reviews/meta-analysis directly related to general mathematics education	Studies lacking a clear research design, data analysis procedures, or empirical evidence; purely descriptive/opinion-based.
Research Results	Studies reporting findings related to mathematical understanding, mathematical competence, or the impact of digital tools on mathematics teaching and learning	Studies that do not report specific learning outcomes or educational impacts related to mathematics education.
Source and Language	Peer-reviewed journal articles, written in the English language, and abstracted within Scopus	Conference proceedings, book chapters, dissertations, technical reports, editorials, short communications, duplicate records, and studies without accessible full text.

2.3. Data Analysis

After coding, the data were processed using descriptive statistics to summarize the frequency of occurrence of the topics. Simultaneously, research groups were divided by topic, commonalities and limitations of studies on each topic were identified, and suggestions were made for future research on these topics.

3. Findings

3.1. Characteristics and Context of the Studies

To highlight the contexts of the publications, they were grouped according to country, journal type, year of publication, and educational level under question; type of digital tools used and field of mathematics covered.

Regarding publication time: Arranging publications by year of publication helps researchers assess the frequency of studies over time. Figure 2 shows that the number of publications increased noticeably after 2021. Although the first publication was released in 2012, the number of publications per year until 2020 was limited at only one; in 2014, 2016, 2017, and 2020, no publication was released at all. The number began to increase to two in 2021 and remained relatively stable from 2022-2025, with 2-3 publications each year. This pattern suggests growing scholarly interest in the application of digital technologies in mathematics education.

Regarding published journals:

Identifying suitable journals for specific purposes is particularly important, helping scientists find appropriate journals for their future publications. Our overview analysis (Table 2) shows that among the 23 reviewed studies, 13 were related to digital technology in mathematics education. All journals were ranked from Q4 to Q1 in terms of quality; according to the Scopus classification available at the time of data collection, IJMEST was ranked Q2 since 2022. Leading the way is the Journal on Mathematics Education with 4 publications; however, this journal is ranked Q3 on Scopus; whereas the second is the Mathematical Thinking and Learning journal with 3 publications, which is ranked Q1 on Scopus.

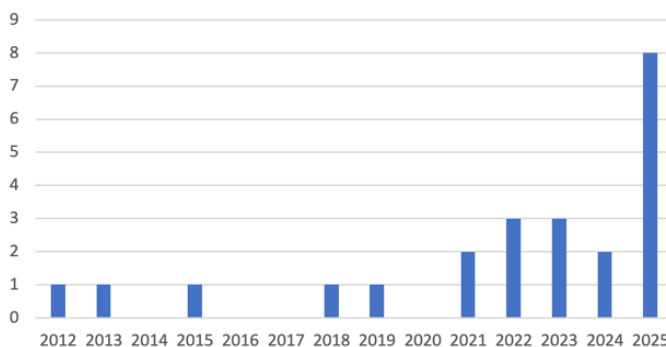


Figure 2. Number of publications by year

Table 2. Publishing Journals of the reviewed studies

Journal	No.	Scopus Ranking
Mathematical Thinking and Learning	3	Q1
International Electronic Journal of Mathematics Education (IEJME)	2	Q4
IJMEST – International Journal of Mathematics Education in Science and Technology	2	Q2 (2022)
Mathematics Education Journal	2	Q2
Journal on Mathematics Education (J. Math. Educ.)	4	Q3
Journal of Mathematical Behavior	2	Q1
ZDM – International Journal on Mathematics Education	2	Q1
Infinity Journal	1	Q3
EURASIA Journal of Mathematics, Science and Technology Education	1	Q2
Annales Mathematicae et Informaticae	1	Q4
IJSE – International Journal of Science Education	1	Q2
Mathematics	1	Q2
Systems	1	Q2

Regarding the authors of the publications: The studies on digital tools in mathematics education are unevenly distributed across regions. Of the 23 publications, Europe (10 articles) and Asia (11 articles) are clearly dominant, while North America has only 2 articles. Indonesia is the country with the most authors (7 articles).

Table 3. Distribution of publications across continents

Continent (Total of publications)	Country
Asia (11)	Indonesia (7), China (1), Taiwan (1), Thailand (1), Israel (1)
Europe (10)	The Netherlands (3), Denmark (1), the Czech Republic (1), Italy (1), North Macedonia (2), Sweden (1), Cyprus (1)
North America (2)	The United States (1), Canada (1)
Total (23)	14 countries/ 23 publications

An overview of the 23 selected studies reveals growing global momentum in integrating educational technologies into math instruction, developing in a diverse and highly international direction, with the participation of scholars from 14 countries across various geographical regions.

Southeast Asia is a prominent region, particularly Indonesia with 7 studies (30.4% of the reviewed publications), mainly focusing on applying the principles of Realistic Mathematics Education within the local cultural context (Laksmiwati et al., 2023). The geographical scope of representation also includes Europe, where digital learning environments are explored, the development of functional thinking is researched, and the evaluation framework is constructed (Mollakuqe & Mollakuqe, 2025; Wei et al., 2025). Embodied learning, the development of students' skills in mathematical representations, and the use of augmented reality (AR) tools are among the topics of studies in North America, East Asia, and the Middle East. In terms of content, the vast majority of papers focus on the application of digital tools such as GeoGebra, Scratch, Animaker, Google SketchUp, and AR/VR technologies for facilitating learners' access to abstract mathematical concepts, namely geometry, statistics, fractions, and vectors (Nurwijayanti et al., 2019; Walkington et al., 2024). These studies are designed to increase engagement, improve visual mathematical representation, decrease cognitive load, and develop digital literacy and computational thinking (Huang et al., 2023; Li et al., 2022; Mollakuqe & Mollakuqe, 2025).

Several research trends can be distinguished beyond the geographical scope of representation. First, the reviewed studies point to a shift from using digital tools for the visualization and conceptualization of mathematical knowledge to modeling, thinking, functional reasoning, and embodied learning. Second, the research methodology predominantly relies on design-based and development-oriented methods, as well as experiments and qualitative research, to assess the effectiveness of digital learning environments and learning processes. Finally, while the majority of studies are conducted in single countries, there is also increasing interest in research collaboration across nations, as demonstrated by a few international papers. The predominance of Asian and European countries on this list suggests that the evidence may be biased toward regional research priorities.

3.2. Methodological Characteristics and Tools Targeted by the Studies

Regarding the level of education of interest, it is evident that the studies on technology use in mathematics teaching have mostly been conducted at the lower secondary level (12 studies, 52.2% of the reviewed literature). At the same time, the number of studies done at the primary level (5 studies, 21.7%) and upper secondary level (6 studies, 26.1%) was significantly lower (Table 4). Among these educational levels, several different types of research design have been used in the included studies, such as design-based research, development research, experimental and quasi-experimental designs, qualitative studies, and mixed methods. The largest group was represented by design-based and development research, which indicates that considerable attention is paid to designing, testing, and improving the technological learning environment in real classroom settings. The studies based on experimental and quasi-experimental designs have mainly focused on evaluating the effectiveness of educational software in relation to mathematics achievement. At the same time, qualitative research has mainly examined students' interactions and reasoning when using digital technologies.

Table 4. Statistics on educational levels and research tools

Level of education	No.	Digital tools used
Primary	5	Desmos, Animaker, Scratch, AR board game, Geometer's Sketchpad
Lower Secondary	12	GeoGebra, Tablet, GeoGebra Classroom, Animated Video, Flipped Classroom, Canva, AR, Google SketchUp, GeoGebra Applets, Excel, GeoGebra Applets
Upper Secondary	6	CAS, GeoGebra, AR, Python, DGS,

As for the tools used in each study, Table 4 presents the distribution of digital tools used in teaching mathematics across different educational levels. In particular, five tools were observed at the primary level. The most common among them were visual and experiential tools such as Desmos, Animaker, Scratch, AR board games, and Geometer's Sketchpad. It should be noted that all those tools focus mainly on concrete representations, exploration, and engagement; thus, they

may be considered highly relevant for primary-level students who are just starting to develop their skills in mathematics. At the lower secondary level, numerous tools were used in 12 studies. They included, but were not limited to, GeoGebra and its variants (GeoGebra Classroom, GeoGebra applets), tablets, animated videos, the flipped classroom model, Canva, AR technology, Google SketchUp, and Excel. It seems that there was a certain transition from concrete experience in mathematics to more complex mathematical reasoning at the secondary level. GeoGebra and its variants are especially important in this case, as these tools enable dynamic visualization and manipulation of mathematical objects, promoting inquiry-based learning. In turn, the tools used at the upper secondary level were computer algebra systems (CAS), GeoGebra, AR technology, Python, and dynamic geometry systems (DGS). Thus, it may be stated that the selection of digital tools depends on students' cognitive development and the complexity of mathematical concepts across different educational levels.

4. Discussion

4.1. The trend of development from assistive technology to technology that constructs mathematical thinking

Overall, a significant change can be traced in the use of digital technology in mathematics education. Digital tools should be viewed as more than calculators and presentation media, as they serve as means of fostering and reshaping students' cognitive actions to promote understanding and reasoning (Vízek et al., 2025). Several studies analyzed in this review emphasize the close connection between students' physical actions (body movements, hand gestures, physical manipulations) and digitized mathematical content represented on tablets or through augmented reality technology (Walkington et al., 2024; Wei et al., 2025). Unlike previous studies focused on symbolic manipulation and static representations of information, these studies show that students can "experience" changes in function and geometric relationships through cognitive-action loops, enabling them to transition from sensory experience to abstract thinking. The reviewed literature also emphasizes that cognitive actions coupled with numerical feedback result in the emergence of cognitive-action loops, which help students understand and grasp abstract concepts (function variation or geometric relationships), in particular (Nisiyatussani et al., 2018; Wei et al., 2025). Moreover, one can trace an increase in the importance of computational thinking as an important approach for mathematics education, where programming and numerical simulation not only involve technical knowledge but also foster problem decomposition, pattern recognition, and algorithmic thinking of students (Huang et al., 2023; Olsson & Granberg, 2022). Overall, the reviewed literature suggests that digital technology is increasingly a partner in cognitive activity in mathematics education, helping students construct meaning in mathematics rather than perform routine actions.

4.2. The pedagogical function of digital tools in school mathematics education

Based on the above review, the value of technological tools lies not only in the tools themselves but also in purposes they serve in the educational process. Many different tools help to promote visualization and dynamic presentation, especially in geometry and functions (Doorman et al., 2012). Software for dynamic geometry (such as GeoGebra and Geometer's Sketchpad) allows students to manipulate mathematical objects to identify their properties and relationships among them (Aliu et al., 2025; Mollakuqe & Mollakuqe, 2025; Ng & Sinclair, 2015). Experiments have shown a clear advantage in students' conceptual understanding when using these tools compared to traditional approaches to teaching (Mollakuqe & Mollakuqe, 2025).

The technological tools serve as means for manipulating, experimenting, and formulating hypotheses. With the help of interactive environments and augmented reality (AR) technologies, students can explore mathematical situations, see how their manipulations affect them, and

conclude (Huang et al., 2023; Shvarts & Helden, 2021). This function helps shift the focus of students' learning from memorizing procedures to exploring mathematical structures.

Digital programming and simulation perform the function of algorithmizing and modeling mathematical thinking. Environments like Scratch, Python, or Logo help students express mathematical ideas in algorithmic form, thereby developing logical thinking and problem-solving skills in topics such as probability, geometry, or arithmetic (Olsson & Granberg, 2022; Seebut et al., 2022). Digital learning environments, including flipped classroom models and technology supported instructional designs demonstrate the function of personalization and support for regulating the learning process; allowing students to learn at their own pace and receive timely feedback (Li et al., 2022; Ramadhani et al., 2024).

4.3. Integration of Digital technology across education levels and cultural contexts

The reviewed studies also show that the level of education and socio-cultural context play an important role, influencing how digital technology is implemented and used. In studies integrating ethnomathematics and cultural contextualization, digital mathematics tasks are designed to be linked to local life, such as traditional calendars, cuisine, or folk games, in order to increase the relevance and significance of mathematics for students (Nursyahidah et al., 2025; Pramudiani & Dolk, 2025; Ramadhani et al., 2024). These investigations indicate that integrating digital technology into a familiar cultural context promotes greater student involvement and the cultivation of mathematical skills. However, the level of contextual dependency poses challenges to the model's generalizability and applicability in other educational environments (Nursyahidah et al., 2025).

The comparison across different levels of education shows significant differences in the tools used and their purposes. Digital technology is widely used in lower levels of education to facilitate learning through visualization and manipulation, whereas at higher levels it is used more often for modeling, programming, and analysis (Olsson & Granberg, 2022; Pedersen et al., 2025). It can be inferred that when incorporating digital technology, teachers need to develop activities that align with the developmental level and mathematical content specific to each grade level.

4.4. Research gaps and policy implications

Although the reviewed studies show many positive results, the analysis also points out some research gaps. The majority of studies have small sample sizes and short intervention periods, limiting the assessment of the long-term impact of digital technology on the development of mathematical thinking (Nursyahidah et al., 2025; Pittalis et al., 2025). Many studies focus on a specific tool or context, while lacking frameworks for comparing the pedagogical functions between different digital tools, especially in long-term and cross-disciplinary research designs (Aliu et al., 2025; Pedersen et al., 2025). Furthermore, the effectiveness of digital technology is also affected by infrastructure factors, the digital divide, and the technological literacy of teachers and students (Aliu et al., 2025; Li et al., 2022; Mollakuq & Mollakuq, 2025).

The use of digital technology places serious demands on teachers' competence in integrating technology into pedagogy. Without a theoretical framework and professional guidance, the use of technology may become a trial-and-error process, obscuring the mathematical nature of learning tasks (Pedersen et al., 2025; Tabach et al., 2013). Hence, one may conclude that future research on this topic should focus on developing theoretical models of digital technology use, based on long-term investigations, professional development for teachers, and equal access to technology for all students, to enhance the use of the possibilities of digital transformation in general mathematics education. Regarding the policy implications, these results emphasize the need to invest in digital infrastructure, especially in schools with limited technological resources (Hidayat & Aripin, 2023). At the same time, the educational authorities should promote programs that will increase teachers' technological and pedagogical competencies and enable the integration of digital technology into mathematics instruction (Laudano, 2021). In addition, guidelines for selecting and using digital technologies across education levels should be established to ensure

that digital transformation facilitates the development of mathematical reasoning and conceptual understanding, rather than the growth of digitization in the classroom (Pittalis et al., 2025). Regarding the Vietnamese education system, the results of the analysis are significant for the processes of digital transformation in education and the General Education Curriculum 2018. The research demonstrates that digital technologies must be used not only as tools of instruction but also as an important means of developing mathematical reasoning and problem-solving skills.

5. Conclusion

The systematic review of 23 studies summarizes scholarship on the adoption of digital technology in school mathematics. It focuses on the role of technology in teaching, its theoretical background, and outcomes for students' learning. The research shows that the use of digital technology offers considerable potential to promote understanding of mathematics when used deliberately and linked to specific instructional goals. However, technology in itself cannot be considered an effective means of education; its effectiveness depends on the organization of learning activities, the mediating role of teachers, and several external factors, such as infrastructure and students' prior knowledge. In the absence of adequate pedagogical assistance, digital technology can lead to superficial learning or even increase inequality in education. The studies analyzed show one clear trend – a gradual transition from considering technology primarily as a means of visualizing and performing mathematical operations to using it as a cognitive partner in doing mathematics. The review also highlights the necessity of conducting research that is more theoretically sound, longer-term, and design-based. From a practical point of view, it is important to note that teacher education programs should pay equal attention to technologies and pedagogical approaches for their integration to promote students' understanding of mathematics. However, the modest number of articles (23) in this study limits the generalizability of the findings to broader contexts. This limitation highlights the need for more in-depth research in the field, while suggesting new exploration directions in the future.

Notes on contributors: Assoc.Prof Dr Huynh Trong Duong, Dr Pham Nguyen Hong Ngu and Bui Xuan Dieu are lecturers in Natural Sciences at Quang Nam University; Dr Pham Nguyen Hong Ngu is lecturer Mathematics and Informatics at Quang Nam, Vietnam. Author 1: Conceptualization, research methods and tools, supervision; author 2: data analysis and manuscript drafting; author 3: data visualization, manuscript writing, and revision.

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