INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 13, Issue 4, (2024) E-ISSN: 2226-6348

Digital Technology Approach in Mathematics Education: A Systematic Review

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To Link this Article: http://dx.doi.org/10.6007/IJARPED/v13-i4/22956 DOI:10.6007/IJARPED/v13-i4/22956

Published Online: 14 October 2024

Abstract

Integrating of digital tools in teaching and learning mathematics has transformed traditional teaching methods. This research involved a systematic review of literature of studies involving the use of digital technology in mathematics education context, focusing on the types of digital tools for teaching mathematics and their effects. Specifically, the review was referring to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines that manage to identify recent articles on two databases (Scopus and ERIC) by following specific inclusion criteria. Based on the analysis, 13 articles published after 2022 have been identified and met the requirement of integrating digital tools in classroom including game-based applications. The findings of the content analysis suggest that students learning outcome, problem-solving skills, engagement and exploration can be improved with the help of digital tools. Overall, the above findings give a deeper comprehension of digital technology and its potential that can influence the process of teaching and learning in mathematics education.

Keywords: Digital, Technology, Approach, Mathematics, Education

Introduction

Digital learning is one of the prominent focus in education nowadays especially mathematics. The idea of digital learning is accepted at almost every level of education (Mulenga & Marbán, 2020; Viberg et al., 2020) especially during pandemic (Engelbrecht et al., 2023). Before pandemic, integrating digital education were always questioned about their effectiveness (Attard & Holmes, 2020). Today, there are many countries integrating technology in their education system has shown positive impact on students' performance (Huda et al., 2024; Vázquez-Cano et al., 2020). Karageorgou (2022), also emphasizes on improving teachers 'digital competencies for Education 4.0. Hence, it is necessary for educators to be responsive to change, from traditional classroom to digital teaching style.

Research on digital education in mathematics has increased significantly and the resources are always up to date. In previous study, some researchers have done review on technology

use in mathematics education focusing in one topic (Hwang et al., 2023) while some focus on specific type of digital tool used such as Augmented Reality (AR) (Fernandes et al., 2023; Hidayat & Wardat, 2023) and GeoGebra (Yohannes & Chen, 2021; Muslim et al., 2023).

Thus, the use of digital tools in mathematics education still raised some critical questions regarding the types of digital tools to be used for different topic and their overall effectiveness (Engelbrecht & Borba, 2023). To address this issues, this study aims to provide systematic review by examining recent studies on digital technology approaches in mathematics education. By evaluating the types of digital tools that are being used in teaching mathematics and exploring the effect of digital tools on students learning, this review seeks to provide valuable insight into how digital technology can affect students' learning.

Research Questions

The purpose of this systematic review is to identify the latest digital tools that are being used in teaching mathematics. It addresses the following research questions:
What are the types of digital tools that are being used in teaching mathematics?
What are the effects of using digital tools on students learning?

Material and Methods

In the following section is the discussion of the flow on how the appropriate papers for this research have been choose. The guidelines, Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) by Moher et al. (2009) were referred. There are four phases of a systematic review which are identification, screening, eligibility and included which will be discussed further under this subtopic.

Identification

The literature search used two major databases, specifically Scopus and ERIC. To identify the keyword recognition, similar terms based on the thesaurus and previous studies were referred. Thus, after all the relevant keywords were decided, search strings on Scopus and ERIC (see table 1) database have been created. In the first step of the systematic review process, 1723 papers from both databases were successfully retrieved.

Table 1
The search string.

Scopus	(("digital technology" OR "educational technology" OR "technology integration" OR "digital tools" OR "ICT") AND ("mathematics education" OR "math education" OR "teaching mathematics" OR "mathematics learning" OR "math instruction")) Date of Access: 4th September 2024
ERIC	AB ((digital technology OR educational technology OR technology integration OR digital tools OR ICT) AND AB (mathematics education OR math education OR teaching mathematics OR mathematics learning OR math instruction)) Date of Access: 4th September 2024

Screening

Next is the screening step. During this process, some criterions were set based on language, timeline, literature type and publication stage (see Table 2). Therefore, 1592 documents have been removed and 130 articles left (105 articles from Scopus and 25 articles from Eric). Then, all the articles were combined and checked for duplication based on the article's title and no article has been removed.

Table 2
The selection criterion

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	≥ 2023	≤ 2022
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

Eligibility

For the third step, 130 articles have been prepared. All the abstracts were read and those that did not meet the requirement have been removed. Only the research conducted in class-setting with the present of students (face to face learning) were chosen. Additional requirement was to include articles under mathematics subjects only. Finally, 13 articles are available for review. Figure 1 shows the flow diagram of the proposed searching study for this research.

Data Abstraction and Analysis

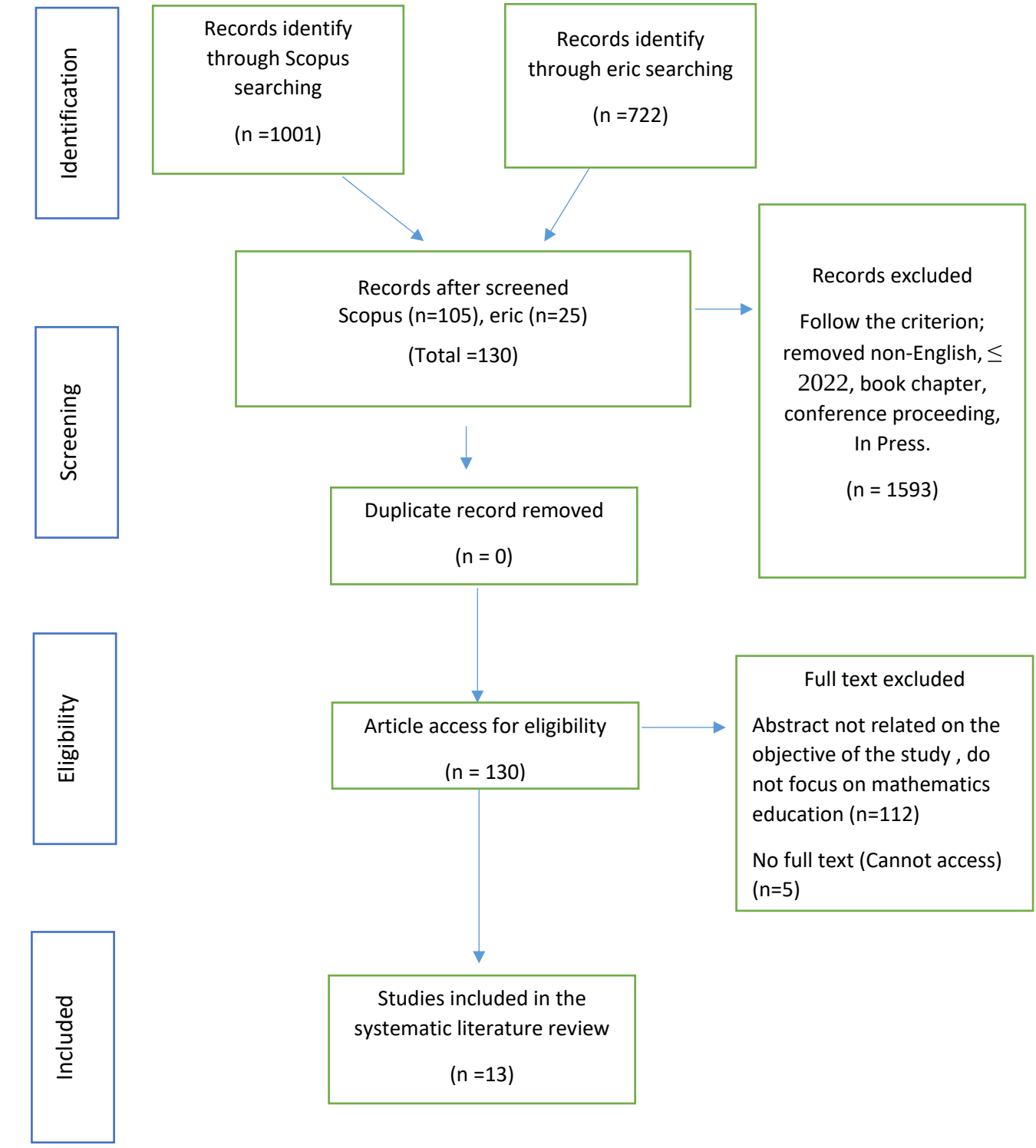

Figure 1: Flow diagram of the proposed searching study (Moher et al., 2009)

Result and Finding

Types of digital tools that are being used in teaching mathematics

Table 3 shows 13 studies related to digital technology in mathematics education. All studies are from different countries except for research by Pittalis and Drijvers (2023) because they

did not mention which country the research has been conducted. Four studies used Trigonometry topic while two studies used Geometry. Seven other studies employed different topics from mathematics, demonstrating that the used of digital tools to teach mathematics can be varies. Two studies by El Bakkali et al. (2023) and Procopio et al. (2024) combine more than one topic in their study while the rest focus on one topic in mathematics. Four studies used quasi-experimental while four other studies used experimental in their study design. There were also case study evaluations. The grade of the samples varied across different levels, including elementary school through college.

Table 3
Studies that used digital tool from different countries together with their study design

Authors	Country	Grade level	Mathematics Topics	Type of digital tools	Study design
Hidayat et al. (2023)	Indonesia	High school	Trigonometry	Android app developed using power point and APK Builder Pro 3.4, Google Form, Interactive worksheets and Videos	Development research using the ADDIE model. Experimental
Jablonski et al. (2023)	Germany	Secondary school (6 - 8th graders)	Linear functions	MathCityMap App	Mixed-method research (quasi-experimental and qualitative)
El Bakkali et al. (2023)	Morocco	Third-year college students	Combinations of few topics including algebra and trigonometry	Kahoot	Experimental
Uwineza et al. (2023)	Japan	Primary-5	Integers	Interactive Mathematics (IM) software	Quasi-experimental
Decker-Woodrow et al. (2023)	United States	Middle School (Grade 7)	Algebra	i- From here to there (game-based) ii- Dragon Box 12+ (game-based) iii- Immediate feedback	Randomized Controlled Trial (RTC) Experimental

Authors	Country	Grade level	Mathematics Topics	Type of digital tools	Study design
				iv- Active control with no immediate feedback	
Pittalis and Drijvers (2023)	Not mention (1 author from Cyprus, 1 from The Netherlands)	11-year-old students (Grade 5)	Geometry	Tablets with multitouch Dynamic Geometry Environments (DGE)	Qualitative methods
Anna Shvarts and Gitte van Helden (2023)	The Netherlands	Secondary school students	Trigonometry	Tablets (Numworks learning environment)	Multiple case study
Annuš and Kmeť (2024)	Slovakia	K-12 (Ages 11-15)	Basic Mathematical Operations	"Learn with M.E." software	Mixed methods
Carriazo-Regino et al. (2024)	Colombia	10th Grade	Trigonometry	GeoGebra	Quasi-experimental
Utaminingsih et al. (2024)	Indonesia	Fourth-grade elementary school students	Fractional numbers	Interactive digital worksheet	Experimental
El Mrabte et al. (2024)	Morocco	High school (average 17.2 years)	Limits and continuity of functions	Graphic tablet vs slide shows	Comparative study
Alviar and Gamorez (2024)	Philippine	Grade 11	Simple and Compound interest	Blickers (Classroom Response System (CRS))	Quasi-experimental
Procopio et al. (2024)	Spain	3rd to 6th Grade (Ages 7-11)	Geometry, operations	Scratch and GeoGebra	Case study evaluation

Many types of digital tools require variety of platforms such as tablet and smartphones to help researchers performing some specific task (Hidayat et al., 2023; Jablonski et al., 2023; El Bakkali et al., 2023; Uwineza et al., 2023; Decker-Woodrow et al., 2023; Pittalis & Drijvers, 2023; Anna Shvarts & Gitte van Helden, 2023; Annuš & Kmeť , 2024; Carriazo-Regino et al., 2024; Utaminingsih et al., 2024; El Mrabte et al., 2024; Alviar & Gamorez, 2024; Procopio et

al., 2024). All these digital tools can be categorized into several key areas. First, app-based learning tools such as MathCityMap, GeoGebra, Numworks, Learn with M.E., DGE and Numworks. Second, gamification tools such as Kahoot, From Here to There and Dragon Box. Third, assessment and feedback such as google forms, Blickers, immediate feedback and no feedback control. Lastly, multimedia learning such as video, slide shows and graphics.

The Effects of using Digital Tools on Students Learning

Table 4 shows the effects of using digital tools on students learning. All 13 researchers have found significant positive impacts on students learning compared to traditional teaching.

Table 4
The effects of using digital tools on students learning

Authors	Effects on students learning
Hidayat et al. (2023)	The achievement on student's mathematical critical thinking who learn using android-based media is better compared to those who learn without android-based media.
Jablonski et al. (2023)	Students that used MathCityMap app solved more task and improved their problem-solving processes by using the hints and feedback from the app. To add, digital feedback has encouraged self-regulated learning activities.
El Bakkali et al. (2023)	The use of gamification using Kahoot has shown higher success percentage than those answer in classical way. Student's self-confidence and motivation also shows some improvement.
Uwineza et al. (2023)	Student's performance shows some improvement by using IM in mathematics class and the use of IM is acceptable by teachers.
Decker-Woodrow et al. (2023)	This study provides evidence to support student's learning under gamification and it is one of the effective ways for students to explore some mathematical concepts effectively.
Pittalis and Drijvers (2023)	Students showed some improvement in their understanding about geometric properties and relationships.
Anna Shvarts and Gitte van Helden (2023)	Students showed some improvement in their understanding of sine graphs through sensory motor tasks
Annuš and Kmeť (2024)	Students showed some improvements in mathematics performance, enhanced engagement and gave positive feedback.
Carriazo-Regino et al. (2024)	Students showed positive impact after integrating GeoGebra in learning Trigonometry.
Utaminingsih et al. (2024)	Students showed some improvement in critical thinking skills and interest in mathematics.

Authors	Effects on students learning
El Mrabte et al. (2024)	Graphics tablet is a recommended tool that can be used in class to enhance students' interest in learning mathematics.
Alviar and Gamorez (2024)	The integration of CRS in mathematics classroom provides higher learning competencies among students than traditional classroom instruction.
Procopio et al. (2024)	Using games as teaching tool showed significant improvement in students' understanding and engagement in mathematics.

Students critical thinking has increased when using digital tools (Hidayat et al., 2023; Uwineza et al., 2023). Additionally, students tend to solve more problem in mathematics when using digital tools and shows high engagement in learning as well as the learning outcomes (Jablonski et al., 2023: Alviar & Gamorez, 2024; Annuš & Kmeť, 2024; El Mrabte et al., 2024; Procopio et al., 2024).By using digital platforms, particularly GeoGebra in topics like trigonometry has enhanced students' ability to understand geometric properties (Carriazo-Regino et al., 2024). Furthermore, incorporating games as digital tools has greatly students' understanding and engagement in mathematics (El Bakkali et al., 2023; Decker-Woodrow et al., 2023).

Discussion and Suggestion

In this systematic review, the types of digital tools that are being used in teaching mathematics have been investigated. These digital tools need to be installed in certain applications to make sure it runs before some studies can be proceeded. They can also be accessed through some platforms such as websites that do not require users to run the application with additional help from internet connection. App-based learning tools provide fun and interactive ways for students to learn mathematics concepts (Anna Shvarts & Gitte van Helden, 2023; Jablonski et al., 2023; Pittalis & Drijvers, 2023; Annuš & Kmeť , 2024; Carriazo-Regino et al., 2024). Gamification tools help to increase students' engagement and make learning more fun (El Bakkali et al., 2023; Decker-Woodrow et al., 2023). Assessment and feedback enable teachers to evaluate students' understanding and get immediate feedback as well as enhancing classroom engagement (Hidayat et al., 2023; Decker-Woodrow et al., 2023; Alviar & Gamorez, 2024). Lastly, multimedia learning helps teachers to support students learning style by making lessons more visually stimulating for students (Hidayat et al., 2023; El Mrabte et al., 2024).

Additionally, the effects of using digital tools on students learning were examined. From the 13 studies under this systematic review, there are many skills had shown when students learn by using digital tools. Table 5 shows all the skills that can be divided into five categories which are cognitive skills, learning and development, emotional skills, technology skills and engagement. All these skills have greater impacts on students' learning.

Table 5
Skills that can be divided into 5 categories

Category	Skills
Cognitive Skills	Critical thinking, problem-solving, understanding concept
Learning and Development	Self-regulated learning, performance improvement
Emotional Skills	Self-confidence, motivation, interest in learning mathematics
Technology Skills	Use of technology (GeoGebra, Apps), gamification, feedback
Engagement	Engagement, Exploration, positive feedback

Cognitive skills, such as critical thinking and problem-solving help students to analyze problems and understand mathematics problems effectively (Hidayat et al., 2023; Uwineza et al., 2023). Learning and development are focusing on students' performance and promotes independent study (Annuš & Kmeť, 2024; Utaminingsih et al., 2024). Emotional skills are prone to intrinsic that are driven by students' motivation and interest in learning mathematics (El Bakkali et al., 2023; Utaminingsih et al., 2024). For engagement it is to ensure that students are still interested in learning and doing the activities (Annuš & Kmeť, 2024).

More research is needed in creating and using digital tools for teaching mathematics to increase students' understanding and motivation. Teachers are also encouraged to expand their horizon in understanding digital skills to ensure that their teaching methods are aligning with students nowadays. It is undeniable that digital skills are essential and need to be sharpen day by day because it is growing rapidly. Teacher assessments on digital skill should be tested periodically to ensure it is on par.

Conclusion

To conclude, this systematic review has identified 13 articles from two databases (Scopus and ERIC). From the analysis, there are many types of digital tools that can be used in teaching mathematics. Some are available for free and some need to be paid. However, more user-friendly software or apps are needed to help students for better understanding and encourage their active learning because many studies show positive impact when using digital tools in learning mathematics.

This research offers both theoretical and practical contributions to our understanding of digital technology approach in mathematics education. On the theoretical side, it synthesizes different digital tools like app-based learning tools, gamification tools, assessment and feedback, and multimedia learning that can help to improve students' understanding and problem-solving skills in mathematics. By reviewing these studies, gaps in the current theories can be identified with some suggestion for further exploration. On a practical level, this review

examines how these technologies are used across different educational level together with their effectiveness. This research is important because it informs educators and policymakers to understand the implementation of digital tools in a way to make mathematics education more accessible and effective for all students.

Funding Statement
This work did not receive any fund from any organisation.

Onflicts of Interest
The authors declare that they have no conflicts of interest to report regarding the present study.

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