The Role of Digital Technology in the Design of Mathematics Teaching and Learning: A Systematic Literature Review

Laila Fitriana[1], Agus Hendriyanto[2], Sani Sahara[3], Lukman Hakim Muhaimin[4], Atik Wintarti[5], Tomi Listiawan[6], Anip Dwi Saputro[7], Deshinta A Dewi[8]
[1]Department of Mathematics Education, Universitas Sebelas Maret, Indonesia
[2]Department of Master's Program in Pedagogy, Nusa Putra University, Sukabumi, Indonesia
[3]Department of Elementary School Teacher Education, Universitas Negeri Jakarta, Jakarta, Indonesia
[4] Department of Elementary School Teacher Education, Nusa Putra University, Sukabumi, Indonesia
[5]Department of Data Science, Universitas Negeri Surabaya, Surabaya, Indonesia
[6]Department of Mathematics Education, Universitas Negeri Malang, Malang, Indonesia
[7]Department of Master's Program in Pedagogy, Universitas Muhammadiyah Ponorogo, Jawa Timur, Indonesia
[8]Center for Data Science and Sustainable Technologies, INTI International University, Malaysia

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ABSTRACT

Purpose of the study: This study systematically reviews the role of digital technologies in the design of mathematics teaching and learning over the past decade. It aims to evaluate how digital tools have been integrated into task and lesson design, identifying emerging trends, challenges, and innovations.

Methodology: A systematic literature review (SLR) following the PRISMA framework was conducted, analyzing studies published between 2014 and 2023. A total of 32 studies were included, sourced from various academic databases. These studies were examined to explore the use of digital technologies such as GeoGebra, Dynamic Geometry Environments (DGE), mobile apps, and others in mathematics instruction.

Main Findings: The review found that digital technologies, particularly GeoGebra and DGE, were frequently used to enhance mathematical exploration and conjecturing. Other tools, including mobile applications, augmented reality (AR), and AI, have contributed to innovative teaching strategies, increasing student engagement and understanding. However, challenges such as unequal access to technology and the need for teacher training in tool integration were identified.

Novelty/Originality of this study: This study provides a unique contribution by focusing not only on the use of digital tools but also on their role within the broader teaching design context. It offers insights into how these technologies shape pedagogical strategies, helping educators design more effective and inclusive mathematics education environments.

Corresponding Author:
Laila Fitriana
Department of Mathematics Education, Universitas Sebelas Maret,
Jalan Ir. Sutami 36 Kentingan, Jebres, Surakarta, Jawa Tengah, 57126 Indonesia
Email: lailafitriana_fkip@staff.uns.ac.id

1. INTRODUCTION

Running for decades, the rapid pace of change in digital technology has significantly impacted education and research. Several studies have mentioned that the pandemic, as a peak of this progression, has transformed the virtual environment into a seamless learning space for students, leading to significant advancements [1]-[6]. The majority of students, specifically the Generation Y and Z, have had opportunities to engage with digital technologies while growing up. They were evolving into more discerning users of technology within the classroom. However, it is yet crucial to acknowledge the argument presented by Kaput and Thompso [7] who asserted that "technology can reinforce any bias the user or designer brings to it". If students fail to perceive the purpose or value of using technology, they may become hesitant to embrace it. When teachers do not actively employ these tools themselves, they do not gain a comprehensive understanding of how students can benefit from them [8]-[10].

In mathematics education research, Drijvers et al. [11] addressed the role of the teacher, educational context, and design as three decisive and crucial key factors to promote the integration of digital technology. The global definition of "design" related to the technology use in mathematics education defined as that technology design should provide an opportunity to make mathematics "more learnable" instead of being the aid to teach school mathematics [7], [12], [13]. Therefore, by using the term "design," we mean not only the design of digital technology involved but also the design of corresponding tasks and activities and the design of lessons and teaching, in general.

There are several terms that describe how digital technology is used in different ways in mathematics education. Borba et al. [14] consider trends of development about the use of digital technology, such as mobile technology as it is capable of expanding mathematics instruction and learning beyond the walls of the classroom. Another is the use of technology in collaborative learning including learning management system (LMS) by Barrot et al. [15]. Moreover, at the more subtle level, the technology development involved "a gradual reshaping or expansion of human experience from direct experience in physical space to experience mediated by the computational medium". In the design manner, and particularly mathematics learning and teaching, the technology should act as interactive tool or as a medium in which one designs and builds interactive artifacts as mathematically expressive media with which to design an appropriate mathematics fitted to the learner.

Regarding the literature review on digital technology tasks and lesson design in mathematics education, numerous studies have been conducted. However, there are limitations in the existing literature reviews as they mainly focus on the end product or specific competencies to be attained. The examples of several literature reviews on digital technology in the past decade are present as follows. We also included these articles in our Systematic Literature Review (SLR) process. By examining the discussions presented in these articles, we aim to review the topics that have been covered thus far and assess how digital technology has been addressed. Subsequently, we will examine how these discussions align with the design context we intend to explore.

Recent studies have offered diverse perspectives on the integration of digital technologies in mathematics education. Rodríguez-Jiménez et al. [16] analyzed publications on the teaching–learning processes of mathematics through information and communication technologies (ICT) in primary education, while Verschaffel et al. [17] examined ICT-based environments designed to foster metacognitively oriented learning in K–12 contexts. In terms of game-based approaches, Hussein et al. [18] synthesized literature on the effectiveness of digital game-based learning (DGBL) applications in K–12 mathematics and provided a systematic review of DGBL, classifying outcomes into knowledge acquisition, perceptual and cognitive skills, and affective, motivational, and behavioral changes, with positive gains reported across categories. Expanding beyond games, Bulut and Ferri [19] reviewed the implementation of augmented reality (AR) in mathematics education, while Tang et al. [20] investigated both the effectiveness of mobile applications and curriculum development for mobile learning, complemented another systematic review of 52 studies that mapped research purposes, approaches, and methods in mobile learning. Artificial intelligence (AI) has also received attention, with Mohamed et al. [21] conducting a systematic review of AI applications in mathematics education, revealing approaches such as robotics, teachable agents, and autonomous systems, and noting the predominance of quantitative studies conducted in the USA and Mexico.

Broader reviews have highlighted overarching trends. Engelbrecht and Borba [22] reviewed significant developments in digital technology in mathematics education over the past five years, focusing on themes such as STEAM integration, critical making, the redefinition of learning spaces, computer algebra systems, dynamic geometry packages, online collaboration, artificial intelligence, and the impact of COVID-19. Hwang et al. [23] performed a large-scale scoping review of more than 2,400 articles on technology in mathematics education (1981–2022), using topic modeling to reveal research trends, popular keywords, and emerging areas of study. At the level of specific tools, Yohannes and Chen [24] systematically reviewed the integration of GeoGebra between 2010 and 2020, finding that most studies were conducted at upper secondary and higher education levels, often focusing on geometry and analysis, and adopting task-based learning strategies. Their review also revealed research gaps, including limited attention to cognitive load, learning anxiety, and student engagement. Collectively, these studies illustrate not only the range of digital technologies applied in mathematics education from ICT, games, AR, AI, and mobile learning to specialized software but also the evolving research landscape that points to both promising outcomes and areas in need of further investigation.

While these previous reviews have provided valuable insights into the integration of digital technology in mathematics education, most of them have primarily concentrated on outcomes such as student achievement, motivation, or the effectiveness of specific tools, without systematically examining how digital technologies are embedded within the design of teaching–learning processesIn other words, existing reviews mainly evaluate technologies as finished products or isolated interventions, paying less attention to how they shape task design, lesson structure, pedagogical strategies, and the overall orchestration of mathematics learning. This represents a critical gap, given that the educational value of technology is not only determined by its inherent features but also by how it is intentionally designed into classroom practices. Therefore, the novelty and contribution of the present review lies in its focused investigation of the role of digital technologies within the design dimension of mathematics teaching and learning. By systematically analyzing how technologies have been conceptualized, adapted, and integrated in lesson and task design over the past decade, this SLR seeks to provide a deeper and more design-oriented understanding of their pedagogical potential. Such an approach not only complements existing reviews but also offers researchers and practitioners a clearer evidence base for designing mathematics learning environments that move beyond technology-as-tool toward its role within the design of mathematics teaching-learning.

In light of these gaps, the present study makes two main contributions. First, it offers a design-oriented synthesis of how digital technologies have been conceptualized and integrated into the design of mathematics teaching and learning over the last decade, going beyond outcome-focused evaluations of isolated tools. Second, it maps the distribution of studies, technologies, mathematical topics, and methodological approaches, thereby providing a comprehensive overview that can inform both future research and classroom practice. To achieve these aims, we conduct a systematic literature review (SLR) following the PRISMA framework, focusing on peer-reviewed journal articles published between 2014 and 2023. The remainder of this article is organized as follows. Section 2 describes the research method and SLR procedures. Section 3 presents the results according to the research questions and discusses the main trends and implications. Section 4 concludes the paper by summarizing the key findings, outlining limitations, and proposing directions for future research.

This study is designed to address several key research questions. First, it examines the distribution of studies over a decade in terms of their publication years. Second, it identifies the types of digital technologies used in the research designs. Third, it explores the mathematical topics addressed in the selected studies. Fourth, it analyzes how the technologies are applied within the research designs. Finally, it investigates the research methodologies employed across the studies.

2. THE COMPREHENSIVE THEORETICAL BASIS

Sierpinska and Kilpatrick [25] emphasized the insufficient level of detailed explanations regarding task designs in mathematics eduction research reports. Nevertheless, in recent times, there has been an increasing focus on task design as a separate field of study, particularly in relation to digital tools. Drijvers et al. [11] describe a generic mathematics task as one that involves students in mathematical activities, enabling them to have meaningful encounters with mathematics. Conversely, a tool-based task is purposefully designed to establish an environment where students can utilize digital tools to actively participate in mathematical experiences [26]-[32].

The term "design" encompasses the notion of achieving goals within a specific environment while fulfilling particular requirements or constraints [33]-[34]. It serves as a strategic approach, providing a roadmap to meet expectations. Design inherently establishes boundaries, offering a structure or framework that fosters the development of meaning and knowledge. Within the domain of task design, the teacher or researcher assumes a vital role in defining and organizing activities within didactic teaching-learning environments [33]-[37]. In this context, technology acts as a defining element that not only sets limits but also shapes the activities undertaken by students and teachers. The design term was also foundationally presented by Simon [38] as the Hypothetical Learning Trajectory (HLT). We may come across tasks where students employ digital tools as supportive aids in problem-solving, without these tools being essential, and the context in which the activities arise need not necessarily be technological.

The use of digital tools in the design of teaching-learning mathematics can be understood as the creation of pedagogical pathways or trajectories that enable the alignment of concepts and the maintenance of coherence across different mathematical domains. According to Drijvers et al. [11], this approach involves a specific method of exploration in technology-rich environments, with the aim of familiarizing students with software and providing them with opportunities to develop various modes of interaction. As students become more comfortable and proficient in using the software, their focus gradually shifts from establishing routine tool usage to actively constructing mathematical meaning. In essence, empirical experiences are transformed into mathematical knowledge. This approach also encourages students to develop the ability to effectively communicate their mathematical reasoning and engage in mathematical argumentation [39]-[44]

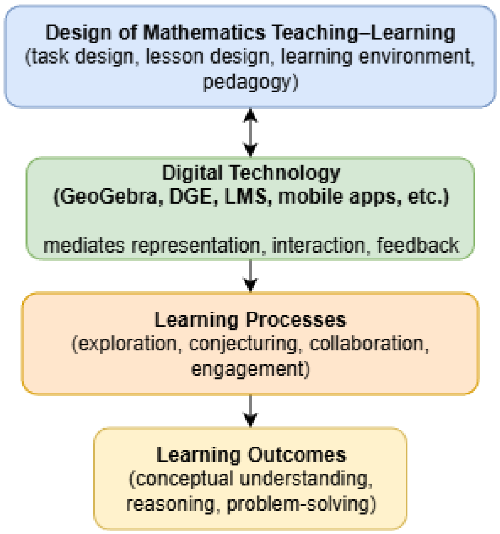

Figure 1. Conceptual framework linking design, digital technology, and mathematics learning processes and outcomes.

3. RESEARCH METHOD

In this section, we outline the research methodology employed for conducting an SLR by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework [45]. PRISMA provides a well-established and transparent procedure for identifying, screening, and synthesizing research evidence, ensuring both methodological rigor and reproducibility. Its stepwise approach comprising identification, screening, eligibility, and inclusion was particularly suited to this review because it allowed us not only to organize and classify digital technologies used in mathematics education but also to conduct a deeper thematic analysis. This analysis aimed to uncover emerging trends, challenges, and pedagogical shifts, while also enabling a comparative perspective with past systematic reviews in the field. By adopting PRISMA, we ensured that the selection process was comprehensive, minimized bias, and facilitated a critical synthesis of both established and novel insights.

3.1. Identification

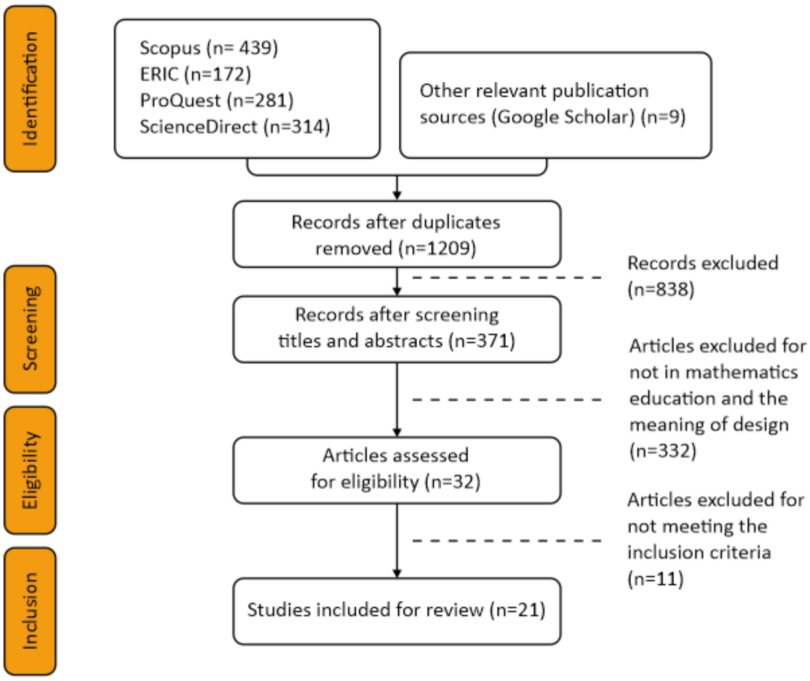

Figure 2. PRISMA diagram

A comprehensive search strategy was developed to identify all potentially relevant studies related to the research question. The search was conducted on May 2023 using predefined search terms and Boolean operators. Various databases were utilized, including Scopus, ScienceDirect, ProQuest, and ERIC. The keywords used in the search were ("Learning Design" OR "Task Design" OR "Learning Model") AND ("ICT" OR "Technology" OR "Digital Technology") AND ("Mathematics" OR "Mathematics Classroom" OR "Mathematics Education"). The results of the search yielded a total of 1,215 records. The distribution of the records across the different databases is as follows: Scopus (439 records), ERIC (172 records), ProQuest (281 records), and ScienceDirect (314 records). In addition to these databases, other sources such as grey literature and reference lists of relevant articles were also examined, resulting in the identification of 9 additional records (see Figure 2).

The initial search aimed to ensure a comprehensive and unbiased search for studies that address the research question. The next step in the systematic review process will involve the screening and selection of these records based on predefined inclusion and exclusion criteria.

3.2. Screening

We proceeded with the screening phase of the study identification process. In this stage, we filtered the initial set of studies based on predefined inclusion and exclusion criteria. These criteria were established to ensure that only studies meeting specific characteristics and relevance to our research question were considered for further evaluation.

The criteria we used encompassed several factors. We considered the publication year, including studies published between 2014 and 2023. This timeframe allowed us to focus on research from decade while still capturing a substantial body of literature. Secondly, we selected studies from indexed journals (Figure 1), as the consideration of reliable and high-quality research. Lastly, we included studies published in English, as it was the primary language for conducting this review. We applied exclusion criteria to eliminate studies that did not meet the defined criteria. For publication year, we excluded studies published before 2014 or after 2023. Additionally, we excluded studies from document types other than indexed journals, as well as studies published in languages other than English. The screening process consisted of two phases: title/abstract screening and full-text screening. During the title/abstract screening phase, we conducted a quick review of the titles and abstracts of the identified studies. This allowed us to exclude studies that were irrelevant to our research question. After this phase, the remaining studies underwent full-text screening, where they were assessed in more detail to determine their eligibility for inclusion in the review.

Following the screening process, we obtained a total of 838 articles that did not meet our criteria. These numbers represent the studies identified from each respective database after removing duplicates. There are 371 articles remaining to proceed to the next phase. We categorized our inclusion and exclusion criteria on the following Table 1.

Table 1. Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Publication year	Published between 2014 and 2023	Before 2014 and after 2023
Document type	Journal articles	Other document types
Language	English	Other languages
Study field	Specific to mathematics education	Other study fields
Technology used	Digital technology in the design of mathematics teaching-learning	Other technology in education

Table 1 summarizes the inclusion and exclusion criteria guiding the screening process. We focused on journal articles published in indexed sources between 2014 and 2023, written in English, and situated specifically within mathematics education. Studies outside this time frame, in other languages, or addressing broader educational fields or non-digital technologies were excluded. These criteria ensured that the review captured recent, peer-reviewed research directly relevant to the design of digital technology in mathematics teaching and learning.

2.3. Eligibility

We applied predefined criteria to evaluate the suitability of the studies that passed the initial screening process for inclusion in our SLR. Our goal was to select studies that align with our research objectives and provide valuable information for the review. To ensure consistency and accuracy, any discrepancies or uncertainties encountered during the eligibility assessment were resolved through discussions among the members of our review team or by seeking consultation from experts in the field.

In this phase, we specifically excluded articles that focused on digital technology in a design manner. Instead, we considered digital technologies that align with our predefined terms of or design as of corresponding tasks and activities and the design of lessons and teaching. Furthermore, we excluded any articles that did not discuss the use of digital technology within the field of mathematics education. This criterion allowed us to narrow down the pool of articles to those specifically related to our research topic.

After conducting a thorough assessment of the collected articles, we identified a total of 32 studies that met our eligibility criteria and were considered for quality appraisal. During this stage, 2 studies were excluded because of insufficient methodological information, and 9 additional studies were excluded due to the unavailability of full text. As a result, 21 articles were retained for inclusion in the final synthesis (see Figure 1).

2.4. Inclusion

In this step, the included studies were catalogued and organized for data extraction and analysis. After applying the quality appraisal and full-text availability criteria, a total of 21 articles were retained and considered for further analysis and review. For each article, we extracted key information including bibliographic details (author, year, country), study design (e.g., case study, experimental, qualitative), participants and educational levels, type of digital technology used, pedagogical strategies or design approaches, and reported outcomes related to mathematics teaching and learning. These categories were selected to align with the review objectives and to enable comparison across studies.

The extracted data were then systematically coded using a standardized coding sheet. Codes captured both descriptive information (e.g., technology type, mathematics topic) and analytical aspects (e.g., role of technology in supporting mathematical thinking, challenges reported, pedagogical implications). Following this, a thematic analysis was conducted to identify recurring patterns, emerging trends, and gaps in the literature. This process ensured that the synthesis addressed not only what technologies were used but also how they shaped the design of mathematics learning environments.

Additionally, the included studies were assessed for their quality and risk of bias to strengthen the reliability of the findings. For our review, we excluded 9 articles due to the unavailability of full text. After this exclusion, a total of 21 articles were retained and considered for further analysis and review. The final set of 21 articles reflects a carefully justified selection process. The restriction to studies published between 2014 and 2023 ensured that the review captured the most recent decade of technological developments, a period marked by rapid innovation and increased integration of digital tools in mathematics education. Limiting the sources to indexed journals guaranteed the inclusion of peer-reviewed and high-quality research, thereby strengthening the reliability of the findings. The choice of English-language studies was pragmatic, as English serves as the dominant medium for disseminating international research, thus maximizing comparability and accessibility. Finally, focusing on mathematics education specifically, rather than broader educational contexts, enabled us to target literature directly relevant to the discipline's pedagogical design issues. These inclusion criteria were therefore essential to ensure that the synthesis addresses the research objectives with depth, clarity, and disciplinary relevance, while also allowing comparison with prior SLRs and identification of new directions.

4. RESULTS AND DISCUSSION

A total of 21 studies were included in the analysis, which aimed to synthesize and evaluate the available evidence on digital technology on the design of mathematics teaching-learning. This section presents the preliminary findings derived from the comprehensive analysis of the included studies according to the research questions.

3.1. Distribution of Studies Based on Year of Publication

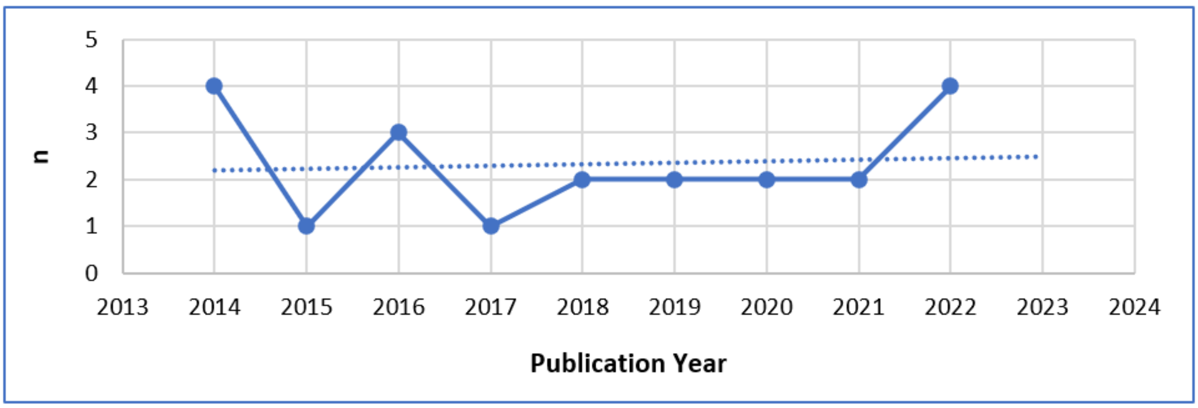

Figure 3. Distribution of Studies Based on Year of Publication

In response to the first research question, we aim to examine the phenomenon of rapid technological advancement over a decade in our research by mapping the year of publication against the number of publications (n), enabling us to assess the trends that occur. The findings revealed that the studies spanned from 2014 to 2023, with a total of 21 publications included in the review. The average number of studies per year was approximately 2. The analysis indicates variations in the number of studies conducted in different years. Figure 3 shows how the trend of the number of publications.

Notably, there was a significant increase in research activity between 2019 and 2022, with five studies published in each of these years. This suggests a growing interest in the subject during this period. In comparison, the years 2014, 2015, and 2016 each had only one study published, indicating a relatively lower level of research activity during those years. Among the included studies, Benton et al. [46] and Barman and Kjällander [47] were the only authors with two publications each, demonstrating their sustained interest in the topic. Overall, the systematic literature review revealed a diverse distribution of studies over the decade, with an increase in research activity in recent years and variations in interest among different authors.

3.2. The digital technologies in the learning design

To initiate the exploration of digital technology, this second research question examines which digital technologies were used in the previously included studies based on the criteria presented in Table 2. The SLR revealed a wide range of digital technologies applied in the design of educational materials. Dynamic Geometry Environments were employed by Fahlgren and Brunström [48], Guerrero-Ortiz and Camacho-Machín [49], and Leung [50]. GeoGebra, another frequently used tool, was reported by Guerrero-Ortiz and Camacho-Machín [49], Ferri et al. [51], Ishartono et al. [52], Nursyahidah and Albab [53], and Kholid et al. [54].

Math Text was utilized by Ahn and Edwin [55], while Mathematical Digital Boundary Objects (MDBO) were discussed by Pedersen et al. [56]. Benton et al. [46] emphasized the use of dynamic and graphical tools, including Computer Algebra Systems (CAS). Other digital technologies identified across the reviewed studies included SimCalc [51], video animation [52], Khan Academy video [45], internet-based learning [53], Digimat [41], web-based learning environments [54], Moodle [55], tablet-based games [56], Mathema [57], iPads [58], and multimedia learning tools [59].

3.3. Mathematical topics addressed

The reviewed studies were also analyzed to identify the mathematical topics addressed. General mathematics emerged as a frequently discussed topic, as highlighted in the works of Fahlgren and Brunström [48], Pedersen et al. [56], Engelbrecht and Borba [22], Tezer et al. [58], Papadimitriou and Gyftodimos [61], and Al-Mashaqbeh [62]. Geometry was another dominant topic, investigated by Guerrero-Ortiz and Camacho-Machín [49], Leung [50], Ishartono et al. [52], Nursyahidah and Albab [53], Kholid et al. [54], Rahajo and Kumyat [44], as well as Komatsu and Jones [64].

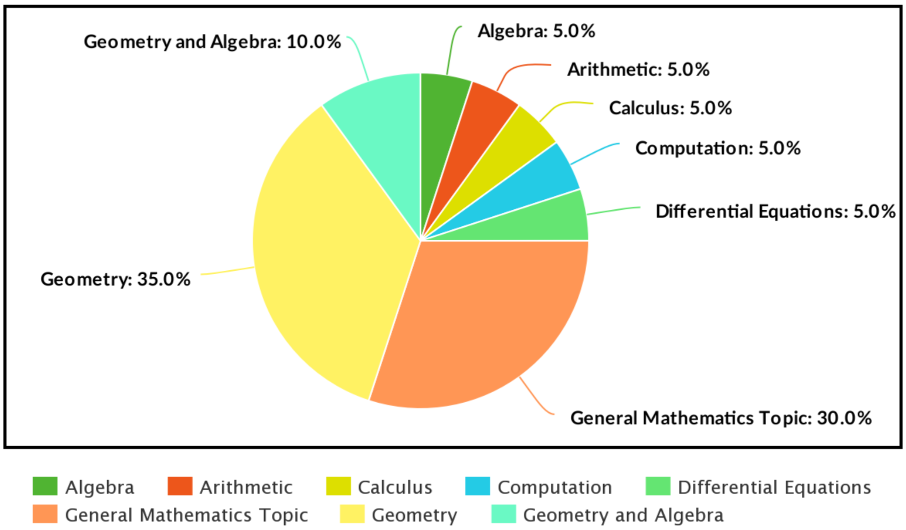

Figure 4. Mathematics Topics Assessed

The intersection of Geometry and Algebra was explored by Fernández et al. [59] and Hoyles et al. [57]. Additionally, Benton et al. [46] also focused on Calculus, while Ahn and Edwin [55] addressed Algebra. Computation was the subject of investigation for Barman and Kjällander [47], and Fernández further examined Differential Equations [59]. Finally, Çakıroğlu's work centered on Arithmetic [63]. By examining these studies collectively, it becomes evident that a wide range of mathematical topics were addressed, including General Mathematics, Geometry, Algebra, Calculus, Computation, Differential Equations, and Arithmetic..

3.4. Digital Technology in the Designs of Teaching-Learning

To address the fourth research question, we catalogued how different digital technologies were positioned within teaching–learning designs in the 21 included studies. Table 3 provides an overview of technologies, publication years, and brief descriptions of how they were integrated into task, lesson, or course designs.

Table 2. Digital technology in the design

Author	Publication Year	Technology Used	How digital technology used in the design
Fernandez et al.	2014	Moodle	By a model with various elements for planning and conducting classroom activities.
Kholid et al.	2014	GeoGebra	With the importance of accurate visualizations and the use of GeoGebra in solving transformation and distance problems
Pedersen et al.	2014	Mathematical Digital Boundary Object (MDBO)	By outsourcing of representation competency when using digital technologies and offered suggestions for designing mathematical tasks.
Hoyles et al.	2014	SimCalc	By balancing closed simulations and open-ended toolkits.
Fahlgren & Brunström	2014	Dynamic Geometry Environments	By engaging mathematical activities such as exploration, conjecturing, explanation, and generalization.
Leung, Allen	2014	Dynamic Geometry Environments	As the pedagogical tool of drag-mode in for generating mathematical conjectures
Waiyakoon et al.	2015	Tablet Game	Using Math Makes Sense Model for promoting mathematical understanding
Çakiroğlu & Taşkin	2016	Multimedia learning environment	As the positive role of interactive and fun activities in improving children's number concept and motivation.
Barrera-Mora & Reyes-Rodriguez	2016	GeoGebra	Using dynamic characteristics of this tool are useful to explore phenomena of change and variation
Al-Mashaqbeh	2016	iPad	Using iPads software for enhancing students' math skills
Papadimitriou & Gyftodimos	2017	Mathema	By implementing and exploiting the following techniques: curriculum sequencing, adaptive presentation, adaptive and meta-adaptive navigation support, interactive problem-solving support, and the adaptive group formation and peer helping.
Ahn & Edwin	2018	Math Text	By a problem-solving activity for teachers using basic geometric ideas
Hoyles et al.	2018	Dynamic Geometry Environments and Computer Algebra Systems (CAS)	The interdependence of learning activities and processes and the potential contributions of design research with digital technologies.
Tezer et al.	2019	Web-based learning environments	By online mathematics learning
Komatsu & Jones	2019	Dynamic Geometry Environments	With principles for using tasks and tools to enhance students' mathematical reasoning
Engelbrecht et al.	2020	Internet	By a new approach in mathematics education, including the design of new settings, social interaction, and tools

Author	Publication Year	Technology Used	How digital technology used in the design
Nursyahidah & Albab	2021	GeoGebra	Using ethnomathematics and Geogebra to support the activity of the volume of a cylinder
Ishartono et al.	2022	GeoGebra	By a three-stage syntax for GeoGebra-based learning media.
Barman & Kjällander	2022	Digimat	Digital resources used for playful learning about digital math, beyond app-based games
Meryansumayeka et al.	2022	Video Animation	By improving students' learning trajectories in cuboid volume.
Guerrero-Ortiz & Camacho-Machín	2022	Dynamic Geometry Environments and GeoGebra	The two currents digital environment associated with the teaching-learning of modelling and mathematics.

As summarized in Table 2, Dynamic Geometry Environments (including GeoGebra) dominate the design landscape, frequently used to support exploration, conjecturing, and visualization in geometry and related topics. Learning management systems such as Moodle tend to structure whole courses or blended learning models, while other tools (e.g., SimCalc, tablet games, iPad, multimedia environments) are more often embedded in specific activities or interventions. Rather than listing each study in detail, the key point is that technologies differ in the level at which they operate in the design: some shape individual tasks, others reconfigure entire learning environments.

3.5. Methodologies used in the research

As part of the review process conducted over a decade, a variety of research studies and their methodologies were examined, as illustrated in Figure 3. The findings revealed that several researchers employed qualitative approaches, including Ahn and Edwin [55], Borba et al. [14], Fahlgren and Brunström [48], Fernández et al. [59], Guerrero-Ortiz and Camacho-Machín [49], Kaput et al. [12], Komatsu and Jones [64], Leung [50], and Pedersen et al. [56].

Furthermore, a group of studies adopted design-based research approaches. Notable researchers in this category included Barman and Kjällander [47], Hoyles et al. [57], Ishartono et al. [52], Meryansumayeka et al. [44], and Nursyahidah and Albab [53]. Design-based research was employed to examine the design and effectiveness of instructional materials, learning environments, and educational interventions..

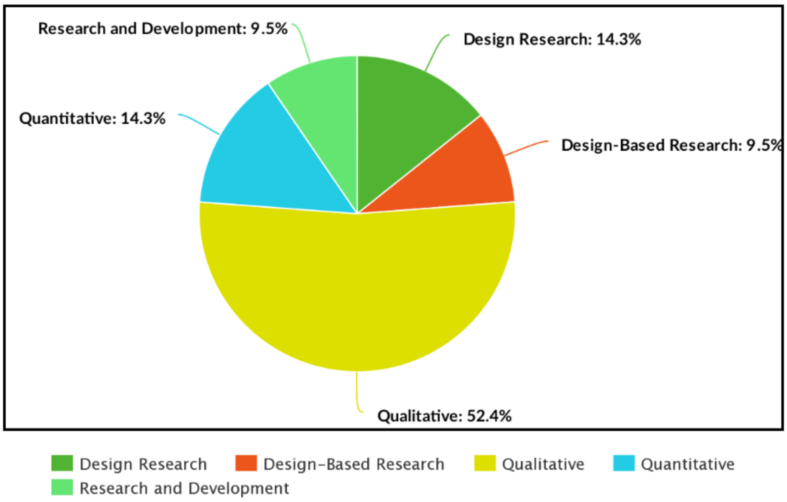

Figure 5. Methodologies used

We also identified several studies that adopted quantitative approaches. Kholid et al. [54] and Tezer et al. [58] employed quantitative methods to collect and analyze numerical data, aiming to generate statistical inferences and generalizable findings. Additionally, Waiyakoon et al. [60] conducted a study using a research and development (R&D) approach. Meanwhile, Papadimitriou [61] employed a qualitative approach, whereas Al-Mashaqbeh [62] utilized a quantitative methodology. Furthermore, Çakıroğlu and Taşkın [63] were also categorized under research and development–based studies.

The findings provide valuable insights of how the design of mathematics teaching-learning employs digital technology. Comparing the findings of the reviewed studies with previous literature reviews in the field open up the discussion we provide in this section.

Earlier of the decade, publication numbers remained low, reflecting the limited availability of advanced technologies and the relatively small research community exploring this intersection [14], [68]. In contrast, recent years show a marked increase in research output, coinciding with greater accessibility of digital tools, more widespread adoption in schools, and external pressures such as the COVID-19 pandemic that accelerated technology use in classrooms [69]-[72]. These trends mirror wider societal shifts toward digitalization [53] and suggest that technology has moved from being a complementary feature to becoming integral to the design of mathematics education.

The patterns identified in this review both align with and diverge from earlier analyses of educational technology in mathematics education. Previous reviews emphasized the transformative potential of digital tools but often noted their limited adoption and scattered impact across topics [12], [73], [74]. The more recent surge of studies confirms the trajectory anticipated by these earlier works, where technology has become embedded not only as a supplement but as an essential part of learning designs. At the same time, our findings indicate a stronger integration of socio-cultural perspectives and interdisciplinary approaches, aspects that were less prominent in older reviews. This suggests that the field is not merely growing in volume but also evolving in theoretical grounding and pedagogical ambition, broadening the scope of how mathematics education is conceptualized through digital means.

A consistent theme across the reviewed studies is the way technology enhances the visual and spatial aspects of mathematics, particularly in geometry. Digital tools such as GeoGebra and other dynamic geometry environments (DGEs) allow for interactive exploration of mathematical entities, making abstract ideas more tangible and supporting skills such as conjecturing and generalization [75]-[77]. The positive impact of such designs has been empirically demonstrated: Ndagijimana et al. [78] found that embedding GeoGebra within a socio-cultural classroom design significantly improved students' understanding of points, lines, and angles compared to traditional instruction. These findings resonate with earlier arguments that mathematics education should focus not only on isolated subject knowledge but also on versatile problem-solving and critical thinking skills [79]-[81]. By situating digital tools within thoughtful designs, educators are able to bridge different domains such as geometry and algebra, aligning with contemporary paradigms of interdisciplinary learning [82]-[85].

Beyond geometry, other technologies highlight how design choices influence outcomes. Shurygin et al. [86] demonstrated that students using the MalMath application outperformed peers in traditional instruction and reported higher motivation, echoing results of prior research on the motivational benefits of mobile applications. Here again, the success was not inherent to the app itself but to its role within a design that positioned technology as central to problem solving and exploration. This illustrates a broader pattern in which digital tools gain pedagogical meaning only when embedded in coherent instructional frameworks.

Nevertheless, the distribution of topics reveals some imbalances. While geometry and general mathematics topics dominate, other areas such as algebra, calculus, computation, differential equations, and arithmetic are less frequently addressed. This uneven focus may reflect challenges in creating digital designs for more abstract or procedural domains, but it also suggests a research gap that merits further exploration. Investigating how digital tools can support these less-studied areas could extend the benefits of technology more broadly across mathematics education. Earlier studies have already highlighted that the role of digital technology in learning design is complex and multifaceted, shaped not only by individual tools but by their synergistic use across topics and contexts [53], [87], [88].

Another important aspect concerns pedagogy and teacher roles. Technology-supported designs are shifting instruction away from rote transmission toward inquiry-based, blended, and student-centered approaches [89]-[91]. Teachers are increasingly positioned as facilitators and designers of digital resources rather than as mere transmitters of knowledge. Weigand et al. [92] emphasizes this shift, pointing to the need to conceptualize teachers' mathematical and digital competencies and to support their long-term development. This aligns with our review, which shows that effective designs integrate digital tools as core components of teaching, learning, and assessment, not as peripheral add-ons.

Despite these promising developments, integrating digital technologies into mathematics education is not without challenges. Several studies highlight issues of unequal access to devices and reliable internet, which can exacerbate educational inequalities [49], [53]. Teacher preparedness remains another critical limitation, as not all educators possess the necessary digital and pedagogical competencies to design effective technology-supported instruction [92]. Furthermore, there are risks of over-reliance on tools, where the novelty of the technology may overshadow deeper mathematical understanding or critical engagement. Addressing these limitations requires sustained professional development, careful consideration of contextual constraints, and policies that ensure equitable access. Acknowledging these challenges not only tempers overly optimistic narratives but also directs attention to the structural and pedagogical conditions under which digital technologies can truly enhance mathematics teaching and learning.

The findings also connect to broader educational aims such as inclusivity and the development of twenty-first century skills. Game-based designs for learners with disabilities illustrate how digital tools can enhance accessibility, while the integration of computational thinking and digital literacy extends the scope of mathematics education to prepare students for a technology-driven society [41], [43], [93]. In early childhood settings, interactive multimedia environments help demystify abstract mathematical ideas, laying foundations for later learning. Together, these examples highlight the breadth of contexts in which technology can enrich learning designs.

3.6.2. Methodological Considerations and Future Directions

From a methodological perspective, the dominance of qualitative and design-based research underscores the field's emphasis on exploring how digital technologies are integrated and iteratively refined [93]-[98]. Quantitative approaches, though less common, provide valuable evidence of impact, as seen in studies such as Ndagijimdana et al. [78] and Shurygin et al. [86]. At times, however, results appear contradictory: while some designs report significant gains in performance and motivation, others highlight limitations or mixed effects [49]. These inconsistencies suggest that context plays a critical role, with factors such as infrastructure, teacher readiness, and cultural learning practices influencing outcomes.

The evidence suggests that the role of digital technology in mathematics education is best understood as dependent design. From GeoGebra's ability to foster socio-cultural interaction to MalMath's effect on motivation, the impact of technology stems from how it is positioned within intentional pedagogical frameworks. While substantial progress has been made in understanding its potential, further research is needed to extend applications to underrepresented mathematical topics, to investigate long-term effects, and to theorize how contextual factors mediate outcomes. By doing so, the field can continue moving toward more equitable, innovative, and evidence-based uses of digital technologies in mathematics education.

Taken together, the present review offers a distinct contribution to the literature by foregrounding the design dimension of digital technology in mathematics education. Whereas many previous reviews have concentrated on learning outcomes or on the effectiveness of particular tools, our synthesis systematically examines how digital technologies are conceptualized and embedded within task, lesson, and learning-environment designs across a decade of research. This design-oriented perspective provides a more nuanced understanding of the pedagogical functions of technology, clarifying the links between design decisions, forms of technological mediation, and observed learning processes and outcomes. Methodologically, the review also highlights the central role of qualitative and design-based approaches in this field, while pointing to underused opportunities for mixed-methods and longitudinal designs that can more robustly capture both the processes and impacts of technology-rich interventions.

The findings carry several implications for both researchers and practitioners. For researchers, the mapped trends suggest the need to extend design-oriented investigations beyond geometry and general mathematics to less-represented domains such as algebra, calculus, computation, and differential equations. Future studies could also more explicitly theorize the role of context (e.g., infrastructure, teacher expertise, socio-cultural factors) in shaping how digital technologies function within designs. For practitioners, the review underlines that technology alone is insufficient; its educational value emerges when it is intentionally integrated into coherent task and lesson designs that promote exploration, conjecturing, reasoning, and collaboration. Teacher education and professional development should therefore focus not only on technical skills, but also on supporting teachers to act as designers of technology-rich learning environments.

This review is subject to several limitations that should be acknowledged explicitly. First, the scope was restricted to peer-reviewed journal articles published in English between 2014 and 2023, which means that relevant work in other languages, conference proceedings, book chapters, or earlier studies may have been excluded. Second, despite using multiple databases and a systematic procedure, the selection remains dependent on the chosen search terms and indexing practices, so some eligible studies may have been missed. Third, the synthesis is based on what authors reported; incomplete methodological descriptions limited the depth of our quality appraisal for some studies. These limitations suggest that future reviews could broaden the range of sources, include non-English publications, and adopt more fine-grained coding frameworks to capture design features and contextual factors in greater detail. Nevertheless, within these boundaries, the present SLR provides a timely and design-focused overview of how digital technology has been integrated into the design of mathematics teaching and learning over the past decade, and offers a foundation for more context-sensitive and theory-driven research in this area.

5. CONCLUSION

This SLR focused on the integration of digital technology in mathematics education, particularly in terms of teaching-learning design. The review identified various digital technologies used in the design of educational materials, including Dynamic Geometry Environment, Geogebra, Math Text, Mathematical Digital Boundary Object (MDBO), and others. The mathematical topics addressed in these studies encompassed General Mathematics, Geometry, Algebra, Calculus, Computation, Differential Equations, and Arithmetic. The review also explored how learning designs incorporated technology. It found that digital technologies provided opportunities for students to engage in mathematical activities such as exploration, conjecturing, explanation, and generalization.

Researchers emphasized the importance of finding the right balance between closed simulations and open-ended toolkits, as well as the interdependence of learning activities and processes. Principles for using tasks and tools to enhance mathematical reasoning were discussed, along with the significance of accurate visualizations and the use of specific tools like GeoGebra. Building on these findings, several directions for further research can be proposed. Future studies could extend design-oriented investigations beyond the currently dominant focus on geometry and general mathematics to under-represented domains such as algebra, calculus, computation, and differential equations. There is also a need for more mixed-methods and longitudinal designs that systematically link design features, classroom implementation, and long-term learning outcomes in authentic settings. In addition, comparative studies across educational levels and contexts could deepen understanding of how infrastructure, teacher expertise, and socio-cultural factors condition the role of digital technologies in design. Given the rapid emergence of artificial intelligence and new interactive environments, future research should also explore how these technologies can be integrated into task and lesson design in ways that promote equity, inclusivity, and the development of higher-order mathematical reasoning.

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The authors used ChatGPT during the preparation of this work to design graphics and images. After utilizing the tool, the authors thoroughly reviewed and edited the content as necessary and assumed full responsibility for the publication's content.

REFERENCES

[1] E. Chung, G. Subramaniam, and L. C. Dass, "Online learning readiness among university students in Malaysia amidst Covid-19," *Asian J. Univ. Educ.*, vol. 16, no. 2, pp. 45–58, 2020, doi: 10.24191/AJUE.V16I2.10294.

[2] B. B. Lockee, "Online education in the post-COVID era," *Nat. Electron.*, vol. 4, no. 1, pp. 5–6, 2021, doi: 10.1038/s41928-020-00534-0.

[3] S. L. Schneider and M. L. Council, "Distance learning in the era of COVID-19," *Arch. Dermatol. Res.*, vol. 313, no. 5, pp. 389–390, 2021, doi: 10.1007/s00403-020-02088-9.

[4] I. Adeoye, A. Adanikin, and A. Adanikin, "COVID-19 and E-Learning: Nigeria tertiary education system experience," *Int. J. Res. Innov. Appl. Sci. (IJRIAS)*, vol. 5, no. 5, pp. 2454–6194, May 2020. [Online]. Available: https://repository.elizadeuniversity.edu.ng/bitstream/20.500.12398/1063/1/researchgateEmailing28-311.pdf

[5] M. Shahrill, M. I. Petra, L. Naing, J. Yacob, J. H. Santos, and A. B. Z. Abdul Aziz, "New norms and opportunities from the COVID-19 pandemic crisis in a higher education setting: Perspectives from Universiti Brunei Darussalam," *Int. J. Educ. Manag.*, vol. 35, no. 3, pp. 700–712, 2021, doi: 10.1108/IJEM-07-2020-0347.

[6] W. Y. Leong, Y. Z. Leong, and W. S. Leong, "Virtual reality on creative learning," in *Proc. 22nd Int. Conf. ICT and Knowledge Engineering (ICT&KE)*, Nov. 2024, pp. 1–4, doi: 10.1109/ICTKE62841.2024.10787163.

[7] J. J. Kaput and P. W. Thompson, "Technology in mathematics education research: The first 25 years in the JRME," *J. Res. Math. Educ.*, vol. 25, no. 6, pp. 676–684, 1994, doi: 10.2307/749579.

[8] O. Viberg, Å. Grönlund, and A. Andersson, "Integrating digital technology in mathematics education: A Swedish case study," *Interact. Learn. Environ.*, vol. 31, no. 1, pp. 232–243, 2023, doi: 10.1080/10494820.2020.1770801.

[9] Z. Noroozi and J. D. V. III, "Teratogenic effects of ethanolic *Cinnamomum burmanni* leaf extract on fetal development in white mice (*Mus musculus* L.)," *J. Acad. Biol. Biol. Educ.*, vol. 2, no. 1, pp. 1–6, 2025, doi: 10.37251/jouabe.v2i1.1657.

[10] E. N. Putri, M. Mahdavi, and M. S. Awlqadir, "An analysis of students' motivation and their achievement in learning English at the Department of English Education," *J. Lang. Lit. Educ. Res.*, vol. 2, no. 1, pp. 43–50, 2025, doi: 10.37251/jolle.v2i1.1698.

[11] P. Drijvers, J. Boaler, S. Gravemeijer, J. Hoyles, and P. K. Noss, "Integrating technology into mathematics education: Theoretical perspectives," in *Mathematics Education and Technology—Rethinking the Terrain*, C. Hoyles and J.-B. Lagrange, Eds., New ICMI Study Series, vol. 13. Boston, MA, USA: Springer, 2009, pp. 89–132, doi: 10.1007/978-1-4419-0146-0_7.

[12] J. Kaput, R. Noss, and C. Hoyles, "Developing new notations for a learnable mathematics in the computational era," in *Handbook of International Research in Mathematics Education*, 1st ed., L. D. English, Ed. New York, NY, USA: Routledge, 2002, pp. 1–26, doi: 10.4324/9781410602541-10.

[13] A. Vasudevan et al., "Unlocking insights of fuzzy mathematics for enhanced predictive modelling," *Appl. Math. Inf. Sci.*, vol. 19, no. 1, pp. 49–59, 2025, doi: 10.18576/amis/190105.

[14] M. C. Borba, P. Askar, J. Engelbrecht, G. Gadanidis, S. Llinares, and M. S. Aguilar, "Digital technology in mathematics education: Research over the last decade," in *Proc. 13th Int. Congr. Mathematical Education*, G. Kaiser, Ed., ICME-13 Monographs. Cham, Switzerland: Springer, 2017, pp. 205–228, doi: 10.1007/978-3-319-62597-3_14.

[15] J. S. Barrot, I. I. Llenares, and L. S. del Rosario, "Students' online learning challenges during the pandemic and how they cope with them: The case of the Philippines," *Educ. Inf. Technol.*, vol. 26, no. 6, pp. 7321–7338, 2021, doi: 10.1007/s10639-021-10589-x.

[16] C. Rodríguez-Jiménez, J. C. de la Cruz-Campos, M. N. Campos-Soto, and M. Ramos-Navas-Parejo, "Teaching and learning mathematics in primary education: The role of ICT—A systematic review of the literature," *Mathematics*, vol. 11, no. 2, 2023, doi: 10.3390/math11020272.

[17] L. Verschaffel, F. Depaepe, and Z. Mevarech, "Learning mathematics in metacognitively oriented ICT-based learning environments: A systematic review of the literature," *Educ. Res. Int.*, vol. 2019, 2019, doi: 10.1155/2019/3402035.

[18] M. H. Hussein, S. H. Ow, M. M. Elaish, and E. O. Jensen, "Digital game-based learning in K–12 mathematics education: A systematic literature review," *Educ. Inf. Technol.*, vol. 27, pp. 2859–2891, 2022, doi: 10.1007/s10639-021-10721-x.

[19] M. Bulut and R. B. Ferri, "A systematic literature review on augmented reality in mathematics education," *Eur. J. Sci. Math. Educ.*, vol. 11, no. 3, pp. 556–572, 2023, doi: 10.30935/scimath/13124.

[20] D. M. Tang et al., "Mobile learning in mathematics education: A systematic literature review of empirical research," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 19, no. 5, 2023, doi: 10.29333/ejmste/13162.

[21] M. Z. bin Mohamed, R. Hidayat, N. N. binti Suhaizi, N. binti M. Sabri, M. K. H. bin Mahmud, and S. N. binti Baharuddin, "Artificial intelligence in mathematics education: A systematic literature review," *Int. Electron. J. Math. Educ.*, vol. 17, no. 3, p. em0694, 2022, doi: 10.29333/iejme/12132.

[22] J. Engelbrecht and M. C. Borba, "Recent developments in using digital technology in mathematics education," *ZDM – Math. Educ.*, vol. 56, no. 2, pp. 281–292, 2024, doi: 10.1007/s11858-023-01530-2.

[23] S. Hwang, E. Flavin, and J.-E. Lee, "Exploring research trends of technology use in mathematics education: A scoping review using topic modeling," *Educ. Inf. Technol.*, vol. 28, no. 8, pp. 10753–10780, 2023, doi: 10.1007/s10639-023-11603-0.

[24] A. Yohannes and H.-L. Chen, "GeoGebra in mathematics education: A systematic review of journal articles published from 2010 to 2020," *Interact. Learn. Environ.*, vol. 31, no. 9, pp. 5682–5697, Dec. 2023, doi: 10.1080/10494820.2021.2016861.

[25] A. Sierpinska and J. Kilpatrick, *Mathematics Education as a Research Domain: A Search for Identity*, vol. 4. Berlin, Germany: Springer Science & Business Media, 2012.

[26] H. Jacinto and S. Carreira, "Mathematical problem solving with technology: The techno-mathematical fluency of a student with GeoGebra," *Int. J. Sci. Math. Educ.*, vol. 15, no. 6, pp. 1115–1136, 2017, doi: 10.1007/s10763-016-9728-8.

[27] Z. Shao, "Task design in mathematics classrooms," in *The 21st Century Mathematics Education in China*, Y. Cao and F. Leung, Eds., New Frontiers of Educational Research. Berlin, Germany: Springer, 2018, pp. 145–162, doi: 10.1007/978-3-662-55781-5_11.

[28] A. M. Canonigo, "Leveraging AI to enhance students' conceptual understanding and confidence in mathematics," *J. Comput. Assist. Learn.*, vol. 40, no. 6, pp. 3215–3229, 2024, doi: 10.1111/jcal.13065.

[29] H. S. Almarashdi, A. M. Jarrah, O. A. Khurma, and S. M. Gningue, "Unveiling the potential: A systematic review of ChatGPT in transforming mathematics teaching and learning," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 20, no. 12, p. em2555, 2024.

[30] M. U. Gusteti, E. Musdi, I. Dewata, and A. M. Rasli, "A ten-year bibliometric study on augmented reality in mathematical education," *Eur. J. Educ. Res.*, vol. 14, no. 3, pp. 723–741, May 2025, doi: 10.12973/eu-jer.14.3.723.

[31] S. Mohammad, Y. N., K. I. Al-Daoud, N. Raja, M. C. R., R. M. H., A. Vasudevan, N. Alshdaifat, and M. F. A. Hunitie, "A mathematical fuzzy model for syntax–pragmatics interface," *Forum for Linguistic Studies*, vol. 7, no. 6, pp. 26–41, 2025, doi: 10.30564/fls.v7i6.9618.

[32] R. D. Siswanto, A. Wahyuni, and R. A. Sholikhakh, "Between innovation and imitation: A phenomenological inquiry into middle school mathematics teachers' credulity in instructional design for quality education," *Lit. Int. J. Soc. Sci. Humanit.*, vol. 3, no. 1, pp. 58–74, Jun. 2024, doi: 10.52005/literate.v3i1.17.

[33] A. Bakker, *Design Research in Education: A Practical Guide for Early Career Researchers*. London, UK: Taylor & Francis, 2018.

[34] R. Cantoral and R. M. Farfán, "Mathematics education: A vision of its evolution," *Educ. Stud. Math.*, vol. 53, no. 3, pp. 255–270, 2003, doi: 10.1023/A:1026008829822.

[35] J. R. Fraenkel, N. E. Wallen, and H. H. Hyun, *How to Design and Evaluate Research in Education*, 7th ed. New York, NY, USA: McGraw-Hill, 2012.

[36] T. T. T. Linh, T. T. M. Huong, and N. Thammachot, "Sustainable nutrient management for NFT hydroponic lettuce: Integrating *Tithonia diversifolia* liquid organic fertilizer with AB-mix," *Integrated Science Education Journal*, vol. 6, no. 3, pp. 240–248, 2025, doi: 10.37251/isej.v6i3.2118.

[37] K. Sehularo, J. Mbogua, and K. Kanifa, "Cardiometabolic effects of *Sus barbatus* meat consumption: Analysis of blood cholesterol levels and cardiac histopathological alterations in *Mus musculus*," *J. Acad. Biol. Biol. Educ.*, vol. 2, no. 1, pp. 16–25, 2025, doi: 10.37251/jouabe.v2i1.1661.

[38] M. A. Simon, "Reconstructing mathematics pedagogy from a constructivist perspective," *J. Res. Math. Educ.*, vol. 26, no. 2, pp. 114–145, 1995.

[39] J. Mata-Pereira and J. P. da Ponte, "Enhancing students' mathematical reasoning in the classroom: Teacher actions facilitating generalization and justification," *Educ. Stud. Math.*, vol. 96, no. 2, pp. 169–186, 2017, doi: 10.1007/s10649-017-9773-4.

[40] N. S. Mohd Rasid and S. Sahara, "Tech-enabled inclusive math education: Reimagining learning for marginalized Indonesian learners in Malaysia," *Lit. Int. J. Soc. Sci. Humanit.*, vol. 3, no. 1, pp. 155–177, Jun. 2024, doi: 10.52005/literate.v3i1.49.

[41] A. Jatmiko, N. Armita, Irwandani, T. Saputro, and M. Aridan, "Development of science learning videos with the Canva application on socioscientific issues content," *E3S Web Conf.*, vol. 482, p. 05004, Jan. 2024, doi: 10.1051/e3sconf/202448205004.

[42] R. Masykur, I. Irwandani, A. Pricillia, and M. Aridan, "Development of science e-modules with the STEM (science, technology, engineering, and mathematics) approach for Islamic schools," *Indones. J. Sci. Math. Educ.*, vol. 7, no. 2, p. 404, Jul. 2024, doi: 10.24042/ijsme.v7i2.20835.

[43] M. Falakhi, T. Khamyod, and M. Jlassi, "Social criticism in Seno Gumira Ajidarma's short stories and its implication for literary learning," *J. Lang. Lit. Educ. Res.*, vol. 2, no. 1, pp. 51–58, 2025, doi: 10.37251/jolle.v2i1.1703.

[44] M. S. Rahajo and A. Kumyat, “Analysis of driving factors for the implementation of clean technology to optimize green manufacturing in the Wiradesa batik small and medium enterprises (SMEs),” *Integrated Science Education Journal*, vol. 6, no. 3, pp. 258–268, 2025, doi: 10.37251/isej.v6i3.2115.
[45] D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman, “Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement,” *Int. J. Surg.*, vol. 8, no. 5, pp. 336–341, 2010, doi: 10.1016/j.ijsu.2010.02.007.
[46] L. Benton, C. Hoyles, I. Kalas, and R. Noss, “Bridging primary programming and mathematics: Some findings of design research in England,” *Digit. Exp. Math. Educ.*, vol. 3, no. 2, pp. 115–138, 2017, doi: 10.1007/s40751-017-0028-x.
[47] L. Barman and S. Kjällander, “Playful and meaningful learning of programming: What does it take to integrate an app-based game promoting digital mathematics into early childhood education?,” *Des. Learn.*, vol. 14, no. 1, pp. 165–178, 2022, doi: 10.16993/dfl.203.
[48] M. Fahlgren and M. Brunström, “A model for task design with focus on exploration, explanation, and generalization in a dynamic geometry environment,” *Technol. Knowl. Learn.*, vol. 19, no. 3, pp. 287–315, 2014, doi: 10.1007/s10758-014-9213-9.
[49] C. Guerrero-Ortiz and M. Camacho-Machín, “Characterizing tasks for teaching mathematics in dynamic geometry system and modelling environments,” *Mathematics*, vol. 10, no. 8, pp. 1–20, 2022, doi: 10.3390/math10081239.
[50] A. Leung, “An epistemic model of task design in dynamic geometry environment,” *ZDM – Int. J. Math. Educ.*, vol. 43, no. 3, pp. 325–336, 2011, doi: 10.1007/s11858-011-0329-2.
[51] F. Ferri, P. Grifoni, and T. Guzzo, “Online learning and emergency remote teaching: Opportunities and challenges in emergency situations,” *Societies*, vol. 10, no. 4, art. no. 86, 2020, doi: 10.3390/soc10040086.
[52] N. Ishartono, A. Nurchayo, M. Waluyo, R. A. Razak, S. Suliadi, and M. Hanifah, “GeoGebra-based flipped learning model: An alternative panacea to improve students’ learning independency in online mathematics learning,” *J. Res. Adv. Math. Educ.*, vol. 7, no. 3, pp. 178–195, Jul. 2022, doi: 10.23917/jramathedu.v7i3.18141.
[53] F. Nursyahida, I. U. Alibab, and I. U. Alibab, “Learning design on surface area and volume of cylinder using Indonesian ethnomathematics of traditional cookie maker assisted by GeoGebra,” *Math. Teach. Res. J.*, vol. 13, no. 4, pp. 79–98, Winter 2021. [Online]. Available: https://eric.ed.gov/?id=EJ1332350
[54] M. N. Kholid, L. N. Pradana, S. Maharani, and A. Swastika, “GeoGebra in project-based learning (Geo-PjBL): A dynamic tool for analytical geometry course,” *J. Technol. Sci. Educ.*, vol. 5, no. 3, pp. 184–193, 2020, doi: 10.3926/jotse.1267.
[55] J. Y. Ahn and A. Edwin, “An e-learning model for teaching mathematics on an open source learning platform,” *Int. Rev. Res. Open Distance Learn.*, vol. 19, no. 5, pp. 256–267, 2018, doi: 10.19173/irrodl.v19i5.3733.
[56] M. K. Pedersen, C. C. Bach, R. M. Gregersen, I. H. Højsted, and U. T. Jankvist, “Mathematical representation competency in relation to use of digital technology and task design—A literature review,” *Mathematics*, vol. 9, no. 4, pp. 1–25, 2021, doi: 10.3390/math9040444.
[57] C. Hoyles, R. Noss, P. Vahey, and J. Roschelle, “Cornerstone mathematics: Designing digital technology for teacher adaptation and scaling,” *ZDM – Int. J. Math. Educ.*, vol. 45, no. 7, pp. 1057–1070, 2014, doi: 10.1007/s11858-013-0540-4.
[58] M. Tezer, E. P. Yildiz, S. Bozkurt, and H. Tangul, “The influence of online mathematics learning on prospective teachers’ mathematics achievement: The role of independent and collaborative learning,” *World J. Educ. Technol. Curr. Issues*, vol. 11, no. 4, pp. 257–265, 2019, doi: 10.18844/wjet.v11i4.4361.
[59] P. Fernandez, M. del C. Rodríguez-Ponce, G. Vega-Cruz, and M. L. Oliveras, “Didactic innovative proposal for mathematic learning at the university by the blended model,” *Procedia – Soc. Behav. Sci.*, vol. 152, pp. 796–801, 2014, doi: 10.1016/j.sbspro.2014.09.323.
[60] S. Waiyakoon, J. Khlaisang, and P. Koraneekij, “Development of an instructional learning object design model for tablets using game-based learning with scaffolding to enhance mathematical concepts for mathematic learning disability students,” *Procedia – Soc. Behav. Sci.*, vol. 174, pp. 1489–1496, 2015, doi: 10.1016/j.sbspro.2015.01.779.
[61] A. Papadimitriou and G. Gyftodimos, “The role of learner characteristics in the adaptive educational hypermedia systems: The case of the MATHEMA,” *Int. J. Mod. Educ. Comput. Sci.*, vol. 9, no. 10, pp. 55–68, 2017, doi: 10.5815/ijmecs.2017.10.07.
[62] I. F. Al-Mashaqbeh, “iPad in elementary school math learning setting,” *Int. J. Emerg. Technol. Learn.*, vol. 11, no. 2, pp. 48–52, 2016, doi: 10.3991/ijet.v11i02.5053.
[63] Ü. Çakıroğlu and N. Taşkın, “Teaching numbers to preschool students with interactive multimedia: An experimental study,” *Çukurova Üniversitesi Eğitim Fakültesi Dergisi*, vol. 45, no. 1, pp. 1–22, 2016. [Online]. Available: https://d1wqtxts1xzle7.cloudfront.net/47753738/Cukurova2016-libre.pdf
[64] K. Komatsu and K. Jones, “Task design principles for heuristic refutation in dynamic geometry environments,” *Int. J. Sci. Math. Educ.*, vol. 17, no. 4, pp. 801–824, 2019, doi: 10.1007/s10763-018-9892-0.
[65] F. Barrera-Mora and A. Reyes-Rodriguez, “Learning technology for education in cloud – The changing face of education,” in *Learning Technology for Education in Cloud*, vol. 620, pp. 168–180, 2016, doi: 10.1007/978-3-319-42147-6.
[66] C. Hoyles, “Transforming the mathematical practices of learners and teachers through digital technology,” *Research in Mathematics Education*, vol. 20, no. 3, pp. 209–228, 2018, doi: 10.1080/14794802.2018.1484799.
[67] N. Ishartono, A. Nurcahyo, and I. D. Setyono, “Guided discovery: An alternative teaching method to reduce students’ rote learning behavior in studying geometric transformation,” *Journal of Physics: Conference Series*, vol. 1265, no. 1, 2019, doi: 10.1088/1742-6596/1265/1/012019.
[68] N. Sinclair and M. Yerushalmy, “Digital technology in mathematics teaching and learning: A decade focused on theorising and teaching,” in *The Second Handbook of Research on the Psychology of Mathematics Education*, Brill, 2016, pp. 235–274.

[69] J. F. Molina-Toro, P. A. Rendón-Mesa, and J. A. Villa-Ochoa, "Research trends in digital technologies and modeling in mathematics education," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 15, no. 8, Art. no. em1736, 2019, doi: 10.29333/ejmste/108438.
[70] M. S. Alabdulaziz, "COVID-19 and the use of digital technology in mathematics education," *Education and Information Technologies*, vol. 26, no. 6, pp. 7609–7633, 2021.
[71] Y. Helsa and S. Yulianti, "Technology liberating or controlling? A critical educational philosophy review of digital systems-based learning," *Literature International Journal of Social Sciences and Humanities*, vol. 3, no. 1, pp. 90–106, Jun. 2024, doi: 10.52005/literate.v3i1.20.
[72] U. Hijriyah, R. N. Edi, M. Aridan, H. U. Hashim, Erlina, and G. C. Kesuma, "How effective is SUNO.AI in enhancing Arabic listening skills? An evaluation of AI-based personalized learning," *International Journal of Information and Education Technology*, vol. 15, no. 2, pp. 391–407, 2025, doi: 10.18178/ijiet.2025.15.2.2251.
[73] R. Pierce and K. Stacey, "Mapping pedagogical opportunities provided by mathematics analysis software," *International Journal of Computers for Mathematical Learning*, vol. 15, no. 1, pp. 1–20, 2010, doi: 10.1007/s10758-010-9158-6.
[74] N. Arya, A. Bansal, R. Kumar, K. Intaratat, and K. T. Ng, "Exploring digital tools utilizing generative AI in healthcare," in *Generative Artificial Intelligence in Healthcare*, Boca Raton: CRC Press, 2025, pp. 54–69, doi: 10.1201/9781003488255-4.
[75] M. Kondratieva, "Geometrical constructions in dynamic and interactive mathematics learning environment," *Online Mevlana International Journal of Education*, vol. 3, no. 3, pp. 50–63, 2013, doi: 10.13054/mije.si.2013.06.
[76] N. N. Le and M. Z. Aye, "The effect of integrating green sustainable science and technology into STEM learning on students' environmental literacy," *Integrated Science Education Journal*, vol. 6, no. 3, pp. 232–239, 2025, doi: 10.37251/isej.v6i3.2116.
[77] A. A. Kambuna, Q.-U. Jatoi, and M. Jlassi, "Language function of selected cosmetics advertisement in online media," *Journal of Language, Literature, and Educational Research*, vol. 2, no. 1, pp. 71–84, 2025, doi: 10.37251/jolle.v2i1.1836.
[78] J.-B. Ndagijimana et al., "Contributions of GeoGebra software within the socio-cultural proximity on enhancing students' conceptual understanding of mathematics," *Cogent Education*, vol. 11, no. 1, p. 2436296, 2024, doi: 10.1080/2331186X.2024.2436296.
[79] A. A. Cuoco and E. P. Goldenberg, "A role for technology in mathematics education," *Journal of Education*, vol. 178, no. 2, pp. 15–32, 1996.
[80] R. Muslim and E. D. Ariyanto, "Digital literacy as a catalyst for future workforce: Enhancing vocational high school graduates' employability in the evolving digital economy," *Literature International Journal of Social Sciences and Humanities*, vol. 3, no. 1, pp. 44–57, 2025, doi: 10.52005/literate.v3i1.29.
[81] M. H. Al-Obaidy, Z. Abdulah, and P. Ratti, "Preventive insights: The role of education in enhancing hypertension patients' knowledge on heart disease," *Journal of Health Innovation and Environmental Education*, vol. 2, no. 1, pp. 11–18, 2025, doi: 10.37251/jhiee.v2i1.1722.
[82] A. Alhikma, I. D. Owoeye, and F. K. Kiara, "Mothers and traditional birth attendants: A phenomenological exploration of childbirth experiences," *Journal of Health Innovation and Environmental Education*, vol. 2, no. 1, pp. 19–30, 2025, doi: 10.37251/jhiee.v2i1.1725.
[83] A. K. Erbas, S. D. Ledford, C. H. Orrill, and D. Polly, "Promoting problem solving across geometry and algebra by using technology," *Mathematics Teacher*, vol. 98, no. 9, pp. 599–603, 2005.
[84] E. Ningsih, "Increasing student learning motivation using inquiry methods in chemistry lessons," *Journal of Chemical Learning Innovation*, vol. 1, no. 1, pp. 7–13, 2024, doi: 10.37251/jocli.v1i1.1017.
[85] K. Khaeratunnafisah and K. Lizbeth, "Utilization of telehealth in improving the quality of health services during the pandemic: A systematic review," *Journal of Health Innovation and Environmental Education*, vol. 2, no. 1, pp. 1–10, 2025, doi: 10.37251/jhiee.v2i1.1723.
[86] 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," *Interactive Learning Environments*, vol. 32, no. 6, pp. 2884–2898, 2024, doi: 10.1080/10494820.2022.2162548.
[87] P. Galbraith, P. Renshaw, and V. Geiger, "Integrating technology in mathematics learning: What some students say," in *Proceedings of the 24th Annual Conference of the Mathematics Education Research Group of Australasia (MERGA)*, 2001, pp. 238–247.
[88] V. Geiger, H. Forgasz, H. Tan, N. Calder, and J. Hill, "Technology in mathematics education," in *Research in Mathematics Education in Australasia 2008–2011*, Brill, 2012, pp. 111–141.
[89] K. Thorne, *Blended Learning: How to Integrate Online and Traditional Learning*, London: Kogan Page, 2003.
[90] N. Islaihah, "Application of cooperative learning methods through sending speeches and questions to improve chemistry learning," *Journal of Chemical Learning Innovation*, vol. 1, no. 1, pp. 14–19, 2024, doi: 10.37251/jocli.v1i1.1028.
[91] S. Charlize, G. R. Semilla, and M. E. Hossain, "Reserving cultural heritage through traditional Filipino games," *Multidisciplinary Journal of Tourism, Hospitality, Sport and Physical Education*, vol. 2, no. 1, pp. 76–82, 2025, doi: 10.37251/jthpe.v2i1.1915.
[92] H.-G. Weigand, J. Trgalova, and M. Tabach, "Mathematics teaching, learning, and assessment in the digital age," *ZDM – Mathematics Education*, vol. 56, no. 4, pp. 525–541, 2024, doi: 10.1007/s11858-024-01612-9.
[93] K. E. Mishra, K. Wilder, and A. K. Mishra, "Digital literacy in the marketing curriculum: Are female college students prepared for digital jobs?," *Industry and Higher Education*, vol. 31, no. 3, pp. 204–211, 2017.
[94] J. W. Creswell and C. N. Poth, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*, Sage Publications, 2016.

[95] R. Lesh, “Research design in mathematics education: Focusing on design experiments,” in *Handbook of International Research in Mathematics Education*, 2002, pp. 27–49.
[96] T. Reeves, “Design research from a technology perspective,” in *Educational Design Research*, Routledge, 2006, pp. 64–78.
[97] J. van den Akker, K. Gravemeijer, S. McKenney, and N. Nieveen, *Educational Design Research*, 1st ed., London, U.K.: Routledge, 2006, doi: 10.4324/9780203088364.
[98] J. van den Akker, K. Gravemeijer, and S. McKenney, “Introducing educational design research,” in *Educational Design Research*, 1st ed., London, U.K.: Routledge, 2006, pp. 1–5. [Online]. Available: https://www.taylorfrancis.com/chapters/edit/10.4324/9780203088364-9/introducing-educational-design-research-jan-van-den-akker-koeno-gravemeijer-susan-mckenne.