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Mobile Learning in Mathematics Education: Trends, Thematic Clusters, Pedagogical Approaches, and Implementation Challenges

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Abstract

Research on mobile learning in mathematics education continues to grow, yet empirical evidence on its actual classroom implementation remains limited. This study aims to comprehensively map the development, knowledge structure, pedagogical approaches, and implementation challenges of mobile learning in mathematics education. The conceptual framework integrates bibliometric analysis and thematic analysis as complementary approaches for understanding the research landscape both quantitatively and qualitatively. The study employed a hybrid review combining bibliometric analysis of 375 publications and thematic analysis of 50 high-quality studies selected from an initial pool of 707 Scopus-indexed records. The findings reveal that mobile learning develops across four main thematic clusters, is dominated by constructivist pedagogical approaches, and faces multi-layered systemic barriers centered on institutional, pedagogical, and individual readiness. Successful implementation is determined by the alignment among technology, instructional design, teacher capacity, and the broader educational ecosystem. These findings provide implications for researchers in identifying future research directions, for educators in designing effective mobile learning environments, and for policymakers in developing comprehensive strategies that support sustainable and equitable mobile learning implementation in mathematics education.

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1. Introduction

Mobile learning, defined as learning supported by mobile devices such as smartphones and tablets that allows access anytime and anywhere, has emerged as a transformative approach in contemporary education (Crompton, 2013). The global penetration of mobile technology has reached unprecedented levels, with GSMA (2023) reporting 6.7 billion unique mobile subscribers worldwide. This widespread availability of mobile devices has created new opportunities for educational innovation, particularly in mathematics education, where interactive, flexible, and personalized learning experiences can significantly enhance student engagement and achievement (Borba et al., 2016).

Mathematics education faces persistent challenges, including abstract concept comprehension, limited student engagement, and difficulties in visualizing complex mathematical relationships. Mobile learning offers potential solutions through interactive applications, augmented reality visualizations, gamification elements, and collaborative platforms that can make mathematics more accessible and engaging (Bano et al., 2018). The integration of mobile technologies in mathematics classrooms enables students to explore mathematical concepts through multiple representations, receive immediate feedback, and engage in problem-solving activities that connect mathematical abstractions to real-world contexts.

Despite the growing body of literature on mobile learning in mathematics education, several gaps remain. First, while numerous studies examine specific mobile learning interventions, comprehensive mapping of the overall research landscape is limited. Second, the relationship between different

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pedagogical approaches and mobile learning implementation remains underexplored. Third, systematic analysis of implementation barriers across technical, individual, and institutional dimensions is lacking. Existing reviews tend to focus on either technological aspects or pedagogical dimensions in isolation, without integrating both perspectives (Hanafi et al., 2025; Kartika, 2023).

This study addresses these gaps by conducting a systematic literature review that integrates bibliometric analysis and thematic analysis to provide a comprehensive understanding of mobile learning in mathematics education. Specifically, this research addresses four research questions:

RQ1: What are the publication trends and knowledge structure of mobile learning research in mathematics education from 2017 to June 2026?

RQ2: What are the main thematic clusters in this research domain?

RQ3: What pedagogical approaches are applied in mobile learning for mathematics education?

RQ4: What are the main implementation challenges faced in mobile learning for mathematics education?

By answering these questions, this study aims to provide researchers, educators, and policymakers with evidence-based insights into the current state, pedagogical foundations, and practical challenges of mobile learning in mathematics education, thereby informing future research directions and implementation strategies.

2. Methods

This study employed a systematic literature review (SLR) methodology integrating bibliometric analysis and thematic analysis to comprehensively examine mobile learning in mathematics education. The research design followed established SLR protocols, including PRISMA guidelines (Moher et al., 2009) and Kitchenham's framework for systematic reviews in educational research (Kitchenham, 2004; Kitchenham & Charters, 2007). The integration of bibliometric and thematic approaches enabled both quantitative mapping of research trends and qualitative understanding of pedagogical practices and implementation challenges.

2.1. Data Source and Search Strategy

The Scopus database was selected as the primary data source due to its comprehensive coverage of peer-reviewed literature, rigorous indexing standards, and provision of complete bibliometric metadata necessary for network analysis. The search was conducted in June 2026, covering publications from January 2017 to June 2026, a period chosen to capture recent developments in mobile learning research following the widespread adoption of smartphones and tablets in educational settings. The publication data for 2026 represent a partial-year period (January–June 2026). Therefore, the publication count for this year should be interpreted cautiously and not be considered directly comparable with the complete annual publication counts of previous years. The search string was designed to capture relevant literature on mobile learning in mathematics education contexts: ("mobile learning" OR "m-learning" OR "mobile-assisted learning" OR "mobile application") AND ("mathematics education" OR "mathematics learning" OR "math education"). The initial Scopus search yielded 707 records. After applying bibliometric filtering procedures and data cleaning, 375 publications were retained for bibliometric analysis. Subsequently, title, abstract, and full-text screening combined with quality assessment resulted in a final sample of 50 studies for thematic analysis.

2.2. Data Source and Search Strategy

To ensure the quality and relevance of included studies, explicit inclusion and exclusion criteria were established prior to the screening process. Table 1 presents the complete criteria applied in this review.

Table 1. Inclusion and Exclusion Criteria

Criteria Dimension	Inclusion Criteria	Exclusion Criteria
Content Focus	Articles focusing on mobile learning, m-learning, mobile-assisted learning, or mobile applications in mathematics education contexts	Articles outside mathematics education contexts; articles focusing solely on general educational technology without specific mobile learning focus

Criteria Dimension	Inclusion Criteria	Exclusion Criteria
Document Type	Journal articles and scientific conference proceedings indexed in Scopus	Editorials, notes, comments, book chapters, books, non-scientific documents, grey literature
Publication Period	Published between January 2017 and June 2026	Published before 2017 or after June 2026
Language	Written in English	Written in languages other than English
Accessibility	Full text accessible through institutional access or open access	Full text not accessible

2.3. Screening and Selection Process

The article selection process followed a systematic multi-stage screening approach as illustrated in Figure 1. The initial Scopus search yielded 707 records. After bibliometric filtering procedures, 375 publications were retained for bibliometric analysis. Subsequently, title and abstract screening resulted in the removal of 287 articles, leaving 88 articles for full-text review.

During the second-stage screening, full texts of the 88 articles were retrieved and assessed for eligibility. Articles were excluded if they lacked sufficient methodological detail, did not provide empirical evidence, or did not directly address mobile learning in mathematics education contexts. This process resulted in 50 articles that met all inclusion criteria and quality standards.

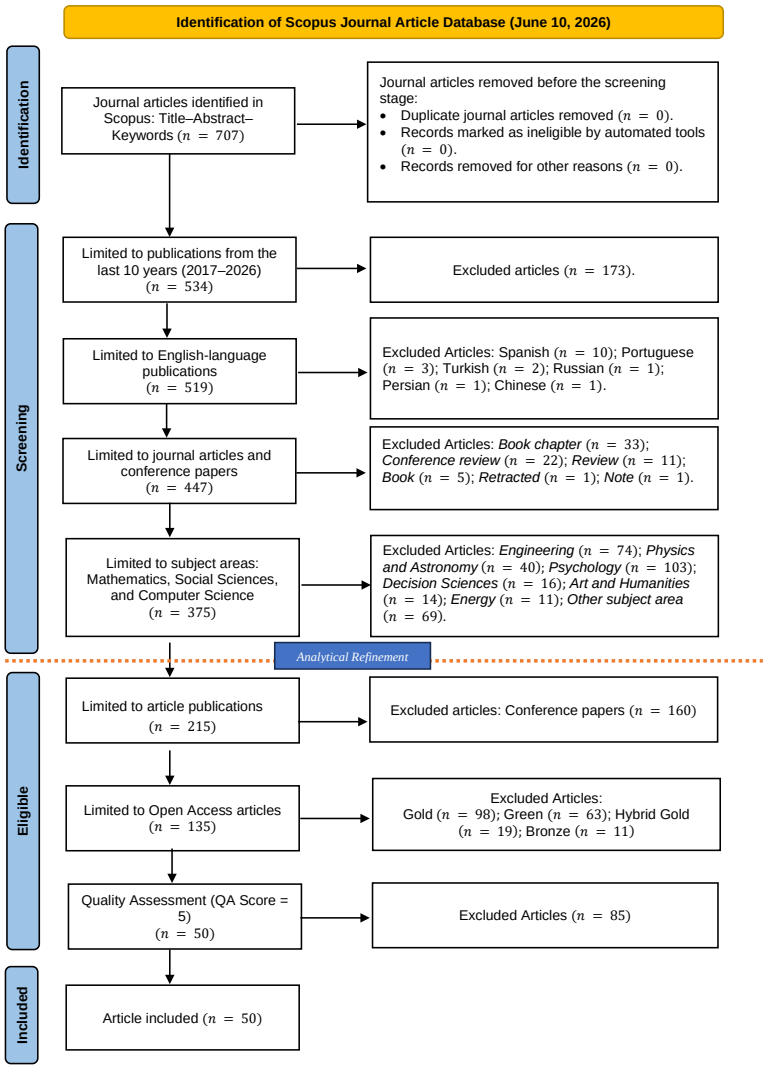


Figure 1. PRISMA Flowchart

2.4. Quality Assessment

To ensure the rigor and reliability of included studies, a quality assessment rubric was applied to all 50 articles. The quality assessment criteria evaluated five dimensions: research design clarity, methodological rigor, data analysis appropriateness, result presentation, and contribution to the field. Each dimension was scored on a scale, with total scores categorized as High (4-5 points), Medium (3 points), or Low (2 points). Table 2 presents the quality assessment framework.

Table 2. Quality Assessment Criteria and Scoring

Quality Dimension	Assessment Criteria	Score Range
Research Design	Clear research questions, appropriate design for objectives, explicit theoretical framework	0-1
Methodological Rigor	Detailed methodology description, appropriate sampling, valid instruments, ethical considerations	0-1
Data Analysis	Appropriate analytical methods, transparent analysis process, reliability and validity addressed	0-1
Results Presentation	Clear presentation of findings, appropriate use of tables/figures, logical organization	0-1
Contribution	Significance of findings, implications for practice/research, limitations acknowledged	0-1
Total Score	Sum of all dimensions	0-5
Quality Category	High: 4-5 points; Medium: 3 points; Low: 2 points	

All 50 articles included in the final analysis achieved quality scores of 2 or above, with the majority scoring in the Medium to High range, ensuring the reliability of findings derived from this corpus.

2.5. Data Extraction and Analysis

The research procedure integrated bibliometric analysis and thematic analysis through a systematic nine-step process as outlined in Table 3.

Table 3. Research Procedure Steps

Step	Procedure	Purpose
1	Formulate research questions	Define scope and objectives of the review
2	Develop search string	Identify relevant keywords and Boolean operators
3	Select database	Choose appropriate database (Scopus) for comprehensive coverage
4	Conduct first screening	Apply inclusion/exclusion criteria to titles and abstracts
5	Finalize bibliometric data	Extract metadata for bibliometric analysis
6	Perform bibliometric analysis	Analyze publication trends, co-occurrence networks, thematic clusters using VOSviewer
7	Conduct second screening	Full-text review and quality assessment
8	Perform thematic analysis	Systematic coding and theme identification following Braun and Clarke (2006)
9	Integrate findings	Synthesize quantitative and qualitative results to answer research questions

Bibliometric Analysis: Bibliometric data including publication year, authors, affiliations, countries, journals, citations, and keywords were extracted from Scopus. VOSviewer software (version 1.6.19) was used to construct and visualize keyword co-occurrence networks, identify thematic clusters, and analyze

research trends. Network maps were generated using association strength normalization, with minimum keyword occurrence thresholds set to ensure meaningful cluster identification.

This study employed a dual-dataset analytical design to accommodate the distinct objectives of bibliometric and thematic analyses. The first dataset consisted of 375 publications obtained after applying bibliometric filtering criteria, including publication period, language, document type, subject area, and accessibility. This dataset was used to examine publication trends, geographic distribution, citation patterns, and keyword co-occurrence networks. The second dataset consisted of 50 articles that met all eligibility criteria and passed the quality assessment process. These articles were subjected to in-depth thematic analysis to identify pedagogical approaches, roles of mobile learning, technology utilization, and implementation challenges. This two-stage approach enabled the study to capture both the broader research landscape and the deeper pedagogical insights within mobile learning in mathematics education.

Thematic Analysis: Following Braun and Clarke's (2006) six-phase framework, thematic analysis was conducted on the full texts of the 50 articles. The analysis focused on identifying pedagogical approaches, mobile learning roles, technology types, and implementation challenges. The coding process involved: (1) familiarization with data through repeated reading, (2) generating initial codes related to pedagogical practices and challenges, (3) searching for themes by grouping codes, (4) reviewing themes for coherence and distinctiveness, (5) defining and naming themes, and (6) producing the final analysis with illustrative examples from the literature.

Data extraction templates were developed to systematically capture information on study characteristics, pedagogical approaches, mobile technologies used, learning outcomes, and reported challenges. Two researchers independently coded a subset of articles to establish inter-rater reliability, with discrepancies resolved through discussion. This integrated methodological approach enabled a comprehensive examination of mobile learning in mathematics education from both macro-level trends and micro-level pedagogical and implementation perspectives, providing robust evidence to address the research questions.

3. Results & Discussions

3.1. Publication Trends and Knowledge Structure

The bibliometric analysis of 375 publications revealed several important trends in mobile learning research in mathematics education. Figure 2 illustrates the annual publication trend, showing a steady increase in research output with notable acceleration after 2020, coinciding with the COVID-19 pandemic's impact on educational technology adoption.

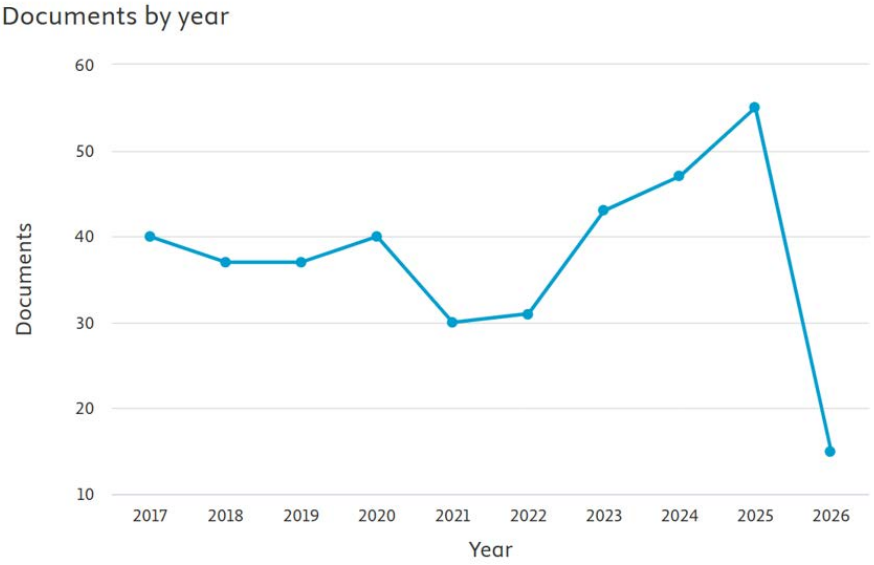


Figure 2. Bar chart showing annual publication trend from 2017 to June 2026

The publication trend demonstrates sustained research interest in mobile learning for mathematics education, with the peak period occurring between 2020 and 2022. This surge reflects the global shift to remote and hybrid learning modalities during the pandemic, which accelerated the adoption and investigation of mobile learning technologies (Crompton & Burke, 2018). Although the 2026 data represent only a partial publication year, the continued research activity observed up to June 2026 suggests that mobile learning remains an active area of investigation as educational institutions continue to integrate technology-enhanced pedagogies into post-pandemic mathematics instruction.

Geographic analysis reveals that research contributions are concentrated in specific regions. The top five contributing countries are Indonesia, Turkey, United States, Taiwan, and Malaysia, collectively accounting for approximately 60% of the reviewed articles. This geographic distribution reflects both the widespread availability of mobile devices in these regions and institutional investment in educational technology research. However, the limited representation from Africa, the Middle East, and Latin America highlights a significant research gap that warrants attention in future studies.

The most frequently cited articles in the corpus include Bano et al. (2018), a systematic review of mobile learning for science and mathematics education with 121 citations, and Borba et al. (2016), a foundational article on blended learning, e-learning, and mobile learning in mathematics education. These highly cited works establish theoretical frameworks and synthesize empirical evidence that subsequent studies build upon, indicating their foundational role in shaping the field.

Leading journals publishing mobile learning research in mathematics education include Computers & Education, Education and Information Technologies, and Eurasia Journal of Mathematics, Science and Technology Education. These outlets provide rigorous peer review and broad dissemination, contributing to the field's scholarly development and practical impact.

3.2. Thematic Clusters in Mobile Learning Research

Keyword co-occurrence analysis using VOSviewer identified four distinct thematic clusters that represent the main research foci in mobile learning for mathematics education. Figure 3 presents the network visualization of these clusters, with node size indicating keyword frequency and link thickness representing co-occurrence strength.

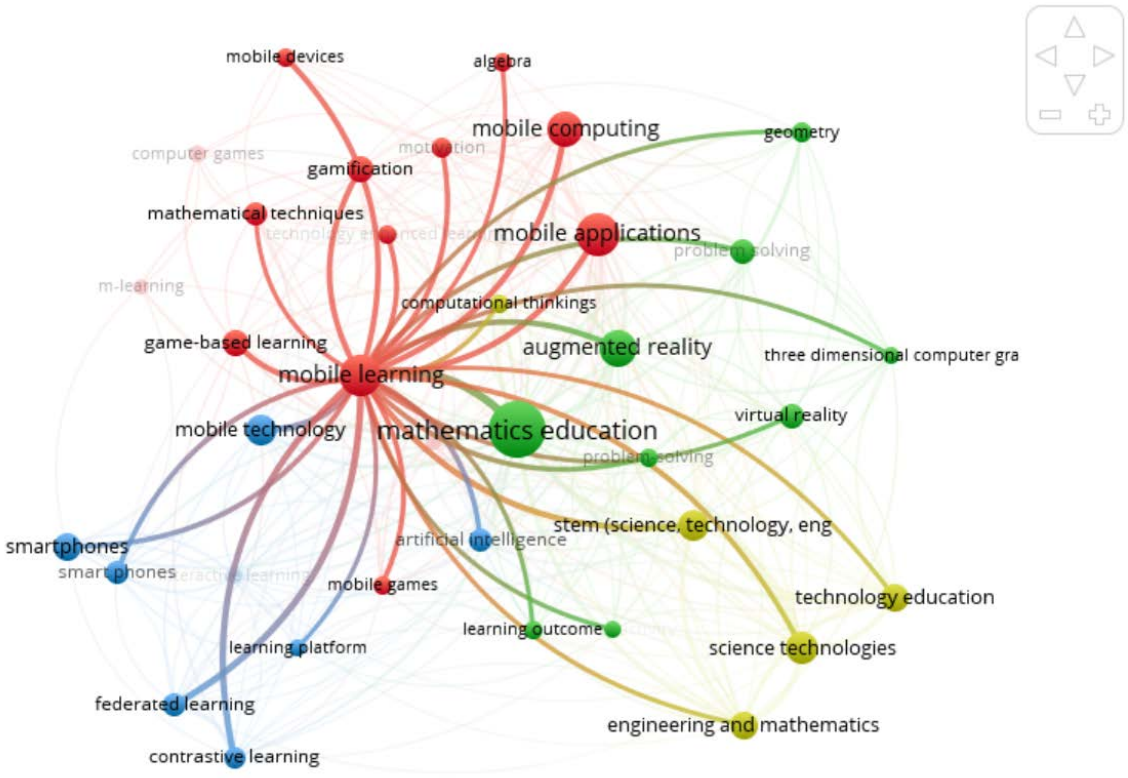


Figure 3. VOSviewer network map showing four color-coded thematic clusters with keyword nodes

3.2.1. Cluster 1 (Red): Technology Integration and Learning Achievement

This cluster focuses on the integration of specific mobile technologies and their effects on mathematics learning outcomes. Key keywords include "mobile application," "achievement," "gamification," "augmented reality," and "virtual reality." Research in this cluster examines how mobile apps, immersive technologies, and game-based elements enhance student achievement, motivation, and engagement in mathematics (Bano et al., 2018). Studies investigate the design and effectiveness of mobile applications for specific mathematical topics such as geometry, algebra, and calculus, often employing experimental or quasi-experimental designs to measure learning gains. The emphasis on achievement reflects the field's concern with demonstrating the educational value of mobile learning investments.

3.2.2. Cluster 2 (Green): Collaborative and Problem-Based Learning

The second cluster emphasizes pedagogical approaches that leverage mobile technologies to facilitate collaborative learning and problem-solving. Keywords include "collaborative learning," "problem solving," "engagement," "peer interaction," and "cooperative learning." Research in this cluster explores how mobile platforms enable students to work together on mathematical problems, share strategies, and construct knowledge collectively (Bringula & Atienza, 2022). Studies examine the design of mobile learning environments that support synchronous and asynchronous collaboration, the role of social interaction in mathematical understanding, and the impact of collaborative mobile learning on problem-solving skills and conceptual development.

3.2.3. Cluster 3 (Blue): Teacher Professional Development and Instructional Design

This cluster addresses the critical role of teachers in successful mobile learning implementation. Key keywords include "TPACK" (Technological Pedagogical Content Knowledge), "teacher training," "instructional design," "professional development," and "teacher competency." Research in this cluster recognizes that effective mobile learning requires teachers to possess integrated knowledge of technology, pedagogy, and mathematics content (Kearney et al., 2012). Studies investigate pre-service and in-service teacher education programs, barriers to technology integration, and the design of professional development interventions that build teachers' capacity to design and facilitate mobile learning experiences in mathematics classrooms.

3.2.4. Cluster 4 (Yellow): Contextual and Culture-Based Learning

The fourth cluster focuses on connecting mathematics learning to students' cultural contexts and real-world experiences through mobile technologies. Keywords include "ethnomathematics," "contextual learning," "Realistic Mathematics Education (RME)," "cultural relevance," and "authentic learning." Research in this cluster explores how mobile learning can bridge formal mathematics and students' everyday experiences, making mathematics more meaningful and accessible (Johnson, 2022). Studies examine mobile applications that incorporate local cultural practices, use of mobile devices for field-based mathematical investigations, and the design of contextually relevant mathematical tasks delivered through mobile platforms.

These four thematic clusters demonstrate the multidimensional nature of mobile learning research in mathematics education, encompassing technological, pedagogical, professional, and cultural dimensions. The clusters are interconnected, with successful mobile learning implementation requiring attention to all four areas. For example, effective technology integration (Cluster 1) depends on appropriate instructional design and teacher capacity (Cluster 3), while collaborative learning approaches (Cluster 2) can be enhanced through culturally relevant contexts (Cluster 4).

3.3. Pedagogical Approaches in Mobile Learning

Thematic analysis of the 50 articles identified diverse pedagogical approaches employed in mobile learning for mathematics education. Table 4 presents the distribution of pedagogical approaches across the reviewed studies. Because thematic categories were not mutually exclusive, a single article could contribute to more than one category. Therefore, the frequencies reported in Tables 4–9 should be interpreted as the number of occurrences of themes across the reviewed studies rather than as independent article counts.

Table 4. Pedagogical Approaches Identified in Mobile Learning for Mathematics Education

Pedagogical Approach Category	Specific Approaches	Number of Articles	Percentage
Constructivist Learning	Problem-Based Learning, Inquiry-Based Learning, Discovery Learning, Experiential Learning	13	26%
Collaborative and Interactive Learning	Collaborative Learning, Cooperative Learning, Peer Learning, Numbered Group Technique, Modified Numbered Group Technique	8	16%
Contextual and Culture-Based Learning	Realistic Mathematics Education (RME), Contextual Learning, Ethnomathematics	5	10%
Technology-Integrated Frameworks	Flipped Classroom, Game-Based Learning, STEM Integration, SAMR Model, TPACK Framework, 4D Model	16	32%
Direct Instruction and Practice	Drill and Practice, Tutorial-Based Learning, Guided Instruction	8	16%

Note: A single study may contribute to multiple categories; therefore, the total frequencies may exceed n = 50.

The findings reveal that Technology-integrated and constructivist approaches were among the most prominent pedagogical orientations identified. Technology-integrated frameworks represent the largest category at 32%, reflecting the field's focus on systematically integrating mobile technologies into mathematics instruction. The TPACK framework is particularly prominent, providing a conceptual lens for understanding the complex interplay between technological, pedagogical, and content knowledge required for effective mobile learning (Kearney et al., 2012). Flipped classroom models leverage mobile devices for pre-class content delivery, freeing classroom time for collaborative problem-solving and teacher-student interaction. Game-based learning approaches use mobile games to increase motivation and engagement while developing mathematical skills through gameplay mechanics.

Constructivist pedagogical approaches appearing in 26% of the reviewed articles. Constructivist approaches including problem-based learning, inquiry-based learning, and discovery learning align well with mobile learning affordances, as mobile devices enable students to explore mathematical concepts actively, test hypotheses, and construct understanding through guided investigation (Borba et al., 2016). Mobile applications that support constructivist learning typically provide interactive simulations, dynamic visualizations, and scaffolded problem-solving environments that allow students to manipulate mathematical objects and observe relationships.

Collaborative and interactive learning approaches appear in 16% of articles, emphasizing the social dimension of mathematical learning. Mobile technologies facilitate collaboration through shared screens, collaborative apps, and communication tools that enable students to work together on mathematical tasks regardless of physical location (Bringula & Atienza, 2022). These approaches recognize that mathematical understanding develops through social interaction, negotiation of meaning, and collective problem-solving.

Contextual and culture-based learning approaches, while less frequent at 10%, represent an important direction for making mathematics more relevant and accessible to diverse student populations. These approaches use mobile technologies to connect formal mathematics to students' lived experiences, cultural practices, and local contexts, thereby increasing engagement and demonstrating the utility of mathematical knowledge (Johnson, 2022).

Based on Table 5, the most universal role of mobile learning is as a facilitator of learning and content delivery, present in all 50 articles. This reflects the fundamental capability of mobile devices to provide access to mathematical content anytime and anywhere, breaking the temporal and spatial constraints of traditional classroom instruction. Mobile learning enables students to access instructional videos, interactive lessons, and digital textbooks on their personal devices, supporting both in-class and out-of-class learning.

Table 5. Roles of Mobile Learning in Mathematics Education

Role of Mobile Learning	Description	Number of Articles
Facilitator of Learning and Content Delivery	Mobile devices serve as primary or supplementary platforms for delivering mathematical content, explanations, and instructional materials	50
Support for Mathematical Problem Solving	Mobile apps provide tools, scaffolds, and environments for solving mathematical problems, including calculators, graphing tools, and problem-solving frameworks	31
Practice and Learning Reinforcement	Mobile platforms offer opportunities for repeated practice, skill development, and reinforcement of mathematical concepts through exercises and drills	11
Assessment and Learning Monitoring	Mobile technologies enable formative and summative assessment, progress tracking, and adaptive feedback based on student performance	14
Interaction and Learning Engagement	Mobile learning facilitates student-student, student-teacher, and student-content interactions that increase engagement and motivation	18

Note: A single study may contribute to multiple categories; therefore, the total frequencies may exceed n = 50.

Support for mathematical problem solving is the second most common role, appearing in 31 articles. Mobile applications provide specialized tools such as graphing calculators, geometry construction software, algebraic manipulators, and step-by-step problem-solving guides that scaffold students' mathematical thinking and enable exploration of complex problems that would be difficult with paper and pencil alone. Mobile learning platforms also increasingly support assessment activities through digital examination features, automated evaluation mechanisms, and question randomization techniques. For example, Maryono et al. (2018) demonstrated that the Fisher–Yates Shuffle algorithm is a reliable method for randomizing question and answer sequences in mobile-based examination systems, thereby supporting more effective and secure assessment practices within instructional media.

The role of mobile learning in facilitating interaction and engagement appears in 18 articles, highlighting the motivational benefits of mobile technologies. Features such as gamification elements, immediate feedback, multimedia presentations, and social interaction capabilities make mathematics learning more engaging and enjoyable, potentially increasing persistence and effort. Table 6 categorizes the types of mobile technologies employed in the reviewed studies.

Table 6. Mobile Technologies Used in Mathematics Education

Technology Category	Specific Technologies	Number of Articles
Personal Mobile Devices	Smartphones, tablets, iPads	30
Mobile Learning Applications	Custom-developed apps, commercial mathematics apps, web-based mobile apps	28
Immersive and Intelligent Technologies	Augmented Reality (AR), Virtual Reality (VR), Artificial Intelligence (AI), Educational robots	7
Web-Based Mobile Platforms	Mobile-responsive websites, learning management systems accessed via mobile browsers	3
Supporting Devices and Tools	Smart glasses, QR codes, mobile sensors	3

Note: A single study may contribute to multiple categories; therefore, the total frequencies may exceed n = 50.

Personal mobile devices, particularly smartphones and tablets, are the most commonly used technology platform, appearing in 30 articles. The ubiquity of these devices among students makes them practical tools for educational interventions without requiring significant additional investment. Mobile learning applications, whether custom-developed for specific mathematical topics or commercial apps adapted for educational use, appear in 28 articles, demonstrating the importance of software design in mobile learning effectiveness.

Emerging technologies including augmented reality, virtual reality, and artificial intelligence appear in 7 articles, representing cutting-edge applications that enhance visualization and interactivity in mathematics learning. AR applications overlay digital mathematical objects onto physical environments, enabling students to manipulate three-dimensional geometric shapes or visualize abstract concepts in concrete ways. AI-powered applications provide adaptive learning experiences that adjust difficulty and content based on individual student performance.

The pedagogical analysis reveals a clear shift from teacher-centered to student-centered instruction in mobile learning environments. Mobile technologies enable personalized learning paths, self-paced progression, and active knowledge construction, aligning with contemporary learning theories that emphasize learner agency and constructivist principles. However, successful implementation requires careful instructional design that aligns technological affordances with pedagogical goals and mathematical content, as reflected in the prominence of TPACK and other integrative frameworks.

3.4. Implementation Challenges

Despite the pedagogical potential and growing adoption of mobile learning in mathematics education, the reviewed literature reveals significant implementation challenges across technical, individual, and institutional dimensions. Understanding these barriers is essential for developing effective strategies to support successful mobile learning integration.

3.4.1. Technical Barriers

Table 7 presents the technical challenges identified in the reviewed studies.

Table 7. Technical Barriers to Mobile Learning Implementation

Technical Barrier Category	Specific Challenges	Number of Articles
Software and Application Problems	App crashes, bugs, compatibility issues, poor user interface design, limited functionality, lack of appropriate apps for specific mathematical topics	15
Device and Infrastructure Limitations	Insufficient devices, outdated hardware, small screen size, limited processing power, battery life constraints	5
Connectivity and Internet Access Issues	Unreliable internet connection, insufficient bandwidth, lack of WiFi access, data cost concerns	12
Limited Physical Laboratory Access	Lack of computer labs or technology-equipped classrooms for mobile learning activities	1
User Adaptation Difficulties	Technical difficulties in using mobile devices and applications, navigation challenges	1

Note: A single study may contribute to multiple categories; therefore, the total frequencies may exceed n = 50.

Software and application problems represent the most frequently reported technical barrier, appearing in 15 articles. These challenges include application instability, poor user interface design that hinders navigation and usability, and lack of appropriate applications for specific mathematical topics or pedagogical approaches (Abidin et al., 2017). The quality and appropriateness of mobile learning applications significantly impact learning effectiveness, yet many available apps lack pedagogical grounding or fail to align with curriculum standards.

Connectivity and internet access issues appear in 12 articles, reflecting the digital divide that persists even as mobile device ownership increases. Many mobile learning applications require internet connectivity for content access, synchronization, or collaborative features, creating barriers for students in areas with limited infrastructure or for families unable to afford data plans. This challenge is particularly acute in developing countries and rural areas, potentially exacerbating educational inequalities.

Device and infrastructure limitations, reported in 5 articles, include insufficient numbers of devices for all students, outdated hardware that cannot run modern applications, and physical constraints such as small screen sizes that make complex mathematical visualizations difficult to view. While mobile devices are increasingly common, not all students have access to devices suitable for educational use, and schools may lack resources to provide devices to all students.

3.4.2. Individual Barriers

Table 8. Individual Barriers to Mobile Learning Implementation

Individual Barrier Category	Specific Challenges	Number of Articles
User Competency and Readiness	Insufficient digital literacy, lack of technical skills, limited experience with mobile learning, teacher technology anxiety	6
Motivation and Learning Engagement	Low student motivation, lack of interest in mobile learning, distraction by non-educational mobile use, difficulty sustaining engagement	7
Self-Regulation and Learning Behavior	Poor time management, procrastination, inability to self-direct learning, lack of discipline in independent mobile learning	5
Cognitive Difficulties in Mathematics Learning	Mathematical anxiety, conceptual misunderstandings, difficulty with abstract concepts, cognitive overload from technology	6
Individual Characteristic Differences	Varying learning styles, prior knowledge differences, age-related differences in technology use, socioeconomic disparities	5

Note: A single study may contribute to multiple categories; therefore, the total frequencies may exceed n = 50.

Motivation and learning engagement challenges appear in 7 articles, highlighting the paradox that while mobile devices can increase engagement through interactive features, they can also serve as sources of distraction. Students may use mobile devices for non-educational purposes during learning time, such as social media, games, or messaging, reducing focus on mathematical tasks. Sustaining long-term engagement with mobile learning requires careful design of motivational elements and classroom management strategies.

User competency and readiness, reported in 6 articles, reflect the reality that not all teachers and students possess the digital literacy skills necessary for effective mobile learning. Teachers may lack confidence in using mobile technologies for instruction, experience technology anxiety, or have insufficient training in mobile learning pedagogy (Abidin et al., 2017). Students may struggle with technical aspects of mobile applications, hindering their ability to focus on mathematical content.

Cognitive difficulties in mathematics learning, appearing in 6 articles, indicate that mobile learning does not automatically resolve fundamental challenges in mathematics education. Students still experience mathematical anxiety, conceptual misunderstandings, and difficulty with abstract concepts even when using mobile technologies. Additionally, poorly designed mobile learning environments can create cognitive overload by presenting too much information simultaneously or failing to provide adequate scaffolding.

Self-regulation and learning behavior challenges, reported in 5 articles, are particularly relevant for mobile learning that occurs outside formal classroom settings. Students must manage their time, set goals, monitor

their progress, and persist through difficulties without direct teacher supervision. Many students lack these self-regulatory skills, leading to procrastination, incomplete learning activities, and suboptimal learning outcomes.

3.4.3. Institutional Barriers

Table 9. Institutional Barriers to Mobile Learning Implementation

Institutional Barrier Category	Specific Challenges	Number of Articles
Teacher Training and Professional Development	Insufficient pre-service teacher preparation, lack of ongoing professional development, limited training in mobile learning pedagogy, absence of technical support for teachers	13
Policy and Institutional Support	Lack of clear mobile learning policies, absence of institutional vision for technology integration, restrictive policies on mobile device use, inadequate administrative support	9
Classroom Implementation Practices	Difficulty integrating mobile learning into existing curriculum, time constraints, classroom management challenges, resistance to pedagogical change	10
Funding and Infrastructure	Insufficient budget for devices and applications, lack of technical infrastructure, inability to maintain and update technology, inequitable resource distribution	11
Human Resources and Technical Expertise	Shortage of technical support staff, lack of instructional designers, insufficient personnel for mobile learning development and maintenance	Multiple articles

Note: A single study may contribute to multiple categories; therefore, the total frequencies may exceed n = 50.

Teacher training and professional development emerge as the most critical institutional barrier, appearing in 13 articles. Effective mobile learning requires teachers to develop integrated technological, pedagogical, and content knowledge (TPACK), yet many teacher education programs provide limited preparation in mobile learning pedagogy (Kearney et al., 2012). In-service teachers often lack access to high-quality professional development that addresses both technical skills and pedagogical strategies for mobile learning. Without adequate preparation and ongoing support, teachers struggle to design effective mobile learning experiences and may revert to traditional instructional methods even when mobile technologies are available.

Funding and infrastructure challenges, reported in 11 articles, reflect the significant financial investment required for sustainable mobile learning programs. Beyond initial device purchases, institutions must budget for application licenses, infrastructure maintenance, technical support, and regular technology updates. Many schools, particularly in under-resourced communities, lack sufficient funding to implement and sustain comprehensive mobile learning programs, creating inequities in access to technology-enhanced mathematics education.

Classroom implementation practices, appearing in 10 articles, highlight the practical difficulties of integrating mobile learning into existing educational structures. Teachers face time constraints in already packed curricula, making it difficult to incorporate mobile learning activities. Classroom management becomes more complex when students use mobile devices, requiring new strategies to maintain focus and prevent off-task behavior. Additionally, mobile learning may require pedagogical changes that challenge traditional teaching practices, encountering resistance from teachers comfortable with established methods. Policy and institutional support challenges, reported in 9 articles, indicate that successful mobile learning implementation requires clear institutional vision and supportive policies. Some institutions lack coherent policies regarding mobile device use in classrooms, creating uncertainty for teachers. Others maintain restrictive policies that prohibit or severely limit mobile device use, preventing teachers from leveraging

these technologies for learning. Effective mobile learning requires institutional leadership that articulates a clear vision, establishes supportive policies, and provides necessary resources and support structures**.**

3.5. Synthesis of Implementation Challenges

The implementation challenges identified in this review demonstrate that successful mobile learning in mathematics education requires addressing interconnected barriers across multiple levels. Technical barriers can be mitigated through investment in infrastructure, selection of high-quality applications, and provision of technical support. Individual barriers require attention to digital literacy development, motivational design, and support for self-regulated learning. Institutional barriers demand systemic changes including comprehensive teacher preparation, supportive policies, adequate funding, and organizational commitment to technology-enhanced pedagogy.

The multi-layered nature of these challenges explains why mobile learning adoption remains uneven despite widespread device availability and growing research evidence of effectiveness. Successful implementation requires alignment among technology, pedagogy, teacher capacity, and institutional support structures. Interventions that address only one dimension while neglecting others are unlikely to achieve sustainable impact. This finding underscores the importance of systemic approaches to mobile learning integration that consider the complex interplay of technical, individual, and institutional factors (Abidin et al., 2017; Bano et al., 2018).

4. Conclusion

By integrating bibliometric analysis of 375 publications and thematic analysis of 50 high-quality studies, this review provides comprehensive insights into mobile learning in mathematics education from 2017 to June 2026, addressing publication trends, thematic clusters, pedagogical approaches, and implementation challenges. The findings contribute to both theoretical understanding and practical guidance for mobile learning integration in mathematics education.

First, publication trends reveal consistent growth in mobile learning research for mathematics education, with significant acceleration following the COVID-19 pandemic. Although the 2026 data represent only a partial publication year, the continued research activity observed up to June 2026 suggests that mobile learning remains an important area of research as educational institutions continue to leverage technology for mathematics instruction. However, geographic concentration of research in specific regions highlights the need for broader international participation, particularly from Africa, the Middle East, and Latin America, to ensure that mobile learning research reflects diverse educational contexts and student populations.

Second, bibliometric analysis identified four main thematic clusters that structure the research landscape: (1) Technology Integration and Learning Achievement, focusing on mobile applications, augmented reality, and gamification; (2) Collaborative and Problem-Based Learning, emphasizing social interaction and problem-solving through mobile platforms; (3) Teacher Professional Development and Instructional Design, addressing the critical role of teacher capacity and TPACK; and (4) Contextual and Culture-Based Learning, connecting mathematics to students' lived experiences through mobile technologies. These clusters demonstrate the multidimensional nature of mobile learning research and the importance of integrating technological, pedagogical, professional, and cultural perspectives.

Third, analysis of pedagogical approaches reveals that technology-integrated frameworks were the most frequently reported category, followed by constructivist approaches. Mobile learning facilitates a shift from teacher-centered to student-centered instruction, enabling personalized learning paths, active knowledge construction, and collaborative problem-solving. The diverse roles of mobile learning, as content delivery platform, problem-solving tool, practice environment, assessment mechanism, and engagement facilitator, demonstrate its versatility in supporting multiple aspects of mathematics education.

Fourth, implementation challenges are multi-layered and systemic, spanning technical, individual, and institutional dimensions. Technical barriers include software problems, connectivity issues, and device limitations. Individual barriers encompass user competency, motivation, self-regulation, and cognitive difficulties. Institutional barriers involve inadequate teacher training, insufficient policy support, implementation difficulties, and funding constraints. The interconnected nature of these challenges indicates that successful mobile learning implementation requires comprehensive approaches that address

all three dimensions simultaneously. Interventions focusing solely on technology provision without attention to pedagogy, teacher capacity, and institutional support are unlikely to achieve sustainable impact.

The findings have important implications for research, practice, and policy. For researchers, the identified thematic clusters and research gaps suggest priorities for future investigation, including longitudinal studies of long-term mobile learning effects, comparative studies across diverse cultural contexts, and research on effective professional development models for mobile learning pedagogy. For practitioners, the pedagogical approaches and implementation challenges identified in this review provide guidance for designing effective mobile learning experiences and anticipating potential barriers. For policymakers, the systemic nature of implementation challenges underscores the need for comprehensive policies that address infrastructure, teacher preparation, curriculum integration, and equitable access.

This study has limitations that should be acknowledged. The focus on Scopus-indexed publications may exclude relevant research published in other venues or languages. The rapid pace of technological change means that findings regarding specific technologies may become dated quickly, though the pedagogical principles and implementation challenges identified are likely to remain relevant. Future research should expand geographic and linguistic scope, conduct longitudinal studies to examine long-term effects of mobile learning, and investigate the sustainability of mobile learning programs beyond initial implementation phases.

In conclusion, mobile learning holds significant promise for enhancing mathematics education through interactive, personalized, and accessible learning experiences. Realizing this promise requires not only technological innovation but also pedagogical expertise, teacher capacity development, and supportive institutional ecosystems. Successful implementation is determined by the alignment among technology, instructional design, teacher capacity, and the broader educational context. As mobile technologies continue to evolve and become increasingly integrated into daily life, their role in mathematics education will likely expand, making continued research and thoughtful implementation strategies essential for maximizing educational benefits while addressing persistent challenges.

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