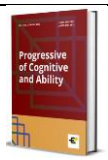
Journal Progressive of Cognitive and Ability
Vol. 04, No. 1, January 2025



e-SSN: 2962-1631, p-ISSN: 2961-9912
https://journals.eduped.org/index.php/jpr

Utilisation of Mobile Learning in Mathematics Education: A Bibliometric Analysis Using The Scopus Database

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Article Info

Revised October 21, 2024
Accepted November 14, 2024

Abstract

The field of education has been profoundly transformed by advancements in information technology, particularly in teaching mathematics. This study thoroughly examines the current research trends in mobile learning (ML) for mathematics education until 2023. This study employed a bibliometric methodology to investigate the distribution patterns of publications in ML to achieve this goal. Specifically, the analysis focused on the following categories: timeline databases, document types of the most prolific countries, commonly used keywords by authors, and the evolution of thematic maps. Two hundred articles retrieved from the Scopus database were analysed and visualised using the Bibliometrix analysis suite from Scintopy software. The findings indicate that ML has emerged as a prominent area of research in mathematics education, with substantial growth observed since 2013, and the year 2019 reached its pinnacle with a record-breaking number of documents, precisely 26. Indonesia had the highest publishing output, with 16 publications, followed by the United States, Malaysia, South Africa, and the Philippines. The current trending subjects revolve around 'mobile learning', 'students', 'mathematics education', and 'e-learning'. There is no text provided. Following these fundamental principles, we can integrate ML in mathematics more comprehensively and extensively, enhancing future educational experiences. This research has the potential to establish a structure for comprehending previous studies and a systematic approach for conducting future research based on empirical evidence.

Keywords: Bibliometric; Database timeline; Mobile learning; Research trends; Scopus database.

How to Cite: Kania, N., Arifin, Z., Rismayani, & Bonyah, E. (2024). Utilisation of Mobile Learning in Mathematics Education: A Bibliometric Analysis Using The Scopus Database. *Journal Progressive of Cognitive and Ability, 4*(1), 8-21, doi: https://doi.org/10.56855/jpr.v4i1.1310.

1. Introduction

The progress in information technology has completely transformed the field of education, particularly in how mathematics is taught. As has been done in learning Joshi et al. (2021), by incorporating digital tools like interactive software, online tutorials, and educational applications, instructors now have a wide range of resources available to improve the learning experience for students. These technologies provide interactive and captivating approaches to instructing intricate mathematical ideas, enabling customised learning encounters catered to the specific needs of each student (Benali & Mak, 2022; Cook et al., 2023; Tondeur et al., 2023). In addition, Castañeda et al. (2022) and Starkey and Yates (2022) affirm that online platforms enhance collaborative learning by providing students with opportunities to engage with classmates and instructors outside the typical classroom setting. Consequently, students acquire enhanced abilities to comprehend intricate mathematical ideas, cultivate analytical reasoning abilities, and employ their knowledge in practical situations. Information technology has revolutionised mathematics education, making it more easily accessible, interactive, and efficient in equipping pupils for triumph in an ever more digitalised society.

An exemplary advancement in education is the implementation of mobile learning. This technique utilises the capabilities of mobile devices such as smartphones and tablets to facilitate acquiring knowledge (Dolgunsöz & Yıldırım, 2021; Seda & Cenk, 2023). Several figures, such as Dwaik et al. (2016) and Greenfield (2009), stated that this method has completely transformed the conventional classroom dynamic by granting students unrestricted access to instructional resources at any time and location. Due to the extensive accessibility of mobile devices and growing internet connectivity, learners can now interact with educational resources outside the traditional classroom setting.

Mobile learning has numerous advantages, such as the ability for students to learn at their speed and in settings that are favourable to their learning preferences (Adzifome & Agyei, 2023; Baars & Viberg, 2022; Gnanasagaran et al., 2023). Moreover, Alzhanova and Chaklikova (2021) reveal that the interactive aspect of mobile applications and educational platforms amplifies student involvement and improves their memory ability. Furthermore, mobile learning accommodates various learning methods, enabling customised learning experiences to meet individual needs and preferences (Fajariyah et al., 2023; Pacholek et al., 2023; Yang & Kuo, 2022). In summary, integrating mobile learning signifies a substantial progression in education, granting pupils enhanced access to educational materials and cultivating a more vibrant and participatory learning atmosphere.

This study employed a bibliometric analysis on the Scientopy platform to investigate the trends and progress in mobile learning, particularly in mathematics education. Bibliometric analysis is a method of analysing publications, citations, and other bibliographic data to understand the patterns and attributes of research on a specific topic (Abdullah, 2022; Ahmed et al., 2023). Using the Scientopy platform, researchers successfully collected and examined a wide range of scientific articles, journals, and publications about mobile learning and mathematical education in an organised manner (Abdullah & Sofyan, 2023). Tas and Bolat (2022) affirmed that bibliometric studies use citation networks and word co-occurrence analysis to detect meaningful patterns and emerging trends in research on mobile mathematics learning. The results of this study can aid academics in accurately monitoring the development and improvement of this discipline by highlighting significant accomplishments in using mobile technology for mathematics instruction.

This comprehensive overview elucidates the diverse applications of technology in mathematics education and emphasises current research trends and intellectual accomplishments. This study can also uncover ambiguity in the literature and guide future research, facilitating the enhancement of

mathematics instruction through the intelligent use of mobile technologies. This compendium of study findings and academic scholarship enlightens educators, researchers, and policymakers on the influence of technology on mathematical education and pinpoint potential avenues for future research and development.

2. Methods

The data collection for this project employs systematic methodologies to guarantee thoroughness and precision. At first, we conducted a literature search using Scopus, Ali et al. (2023), a prominent database and search engine. A meticulous curation of articles on using technology in mathematics instruction was conducted. Once relevant articles are located, a series of preprocessing steps is employed to cleanse the data. This entails evaluating articles according to specific inclusion and exclusion criteria to guarantee their relevance to the study objectives (Caingcoy, 2021). In addition, any duplicate entries were eliminated from the data sets Sofyan et al. (2022). Following data collection, a review is conducted to analyse the piece. To comprehensively understand mobile learning in mathematics education, it is essential to meticulously examine the methodology, fundamental principles, and practical implications outlined in each article. This programme aims to curate and showcase cutting-edge research and valuable resources for educators, policymakers, and researchers interested in leveraging mobile technology to enhance the quality of mathematics instruction.

2.1. Collection of data and preliminary analysis

The Scopus data was available on Mach 1, 2024. This study utilises the phrases "("mobile learning" OR "mobile application" OR "machine learning" OR "m-learning" OR "mobile devices" OR "mobile technologies" OR "mobile technology" OR "mobile app" AND "math education" OR "mathematics education" OR "teaching mathematics" OR "teaching math" OR "learning mathematics" OR "learning math"). This term collects pertinent articles, conferences, and reviews. It is essential to take this step to guarantee that the dataset encompasses a diverse range of sources that can offer a complete comprehension of mobile technology utilisation in mathematics instruction. Scopus data enables academics to locate and access valuable sources of information that can be utilised for in-depth analysis and subsequent research (Gazali et al., 2023; Kania et al., 2023).

Table 1. Details on the preliminary examination of data

Data Retrieval	Number	Percentage
Loaded papers	235	-
Omitted papers by document type	32	13.60
Total papers after omitted papers removed	203	-
Loaded papers from Scopus	203	100.00
Duplicated removal results:	-	-
Duplicated papers found	1	0.50
Removed duplicated papers from Scopus	1	0.50
Duplicated documents with different cites by	1	100
Total papers after rem. Dual.	202	-
Papers from Scopus	202	100

Table 1 presents the 202 papers that were part of this study sample after eliminating any duplicate entries. When removing duplicates, keep at least 300 articles that analyse metrics. ScientoPy guaranteed data accuracy and prevented duplicates (Ruiz-Rosero et al., 2019). ScientoPy analyses downloaded data to discover frequently researched subjects and uses appropriate publishing criteria

(Rosiyan, 2023). The database had 688 papers from January 1, 1990, to December 31, 2023, including scholarly articles, conference proceedings, critical reviews, and book chapters. ScientoPy aids researchers in verifying the credibility, comprehensiveness, and pertinence of the dataset to their goals. By utilising this approach, the integrity of research data is protected, and the likelihood of duplication is reduced, reducing the possibility of biased analytical results.

3. Results and Discussion

3.1. Results

3.1.1 The Progression of Printed Materials

Scientific publications generally offer substantial advantages to researchers and the institutions that publish them. Publications serve as a crucial medium for researchers to share the outcomes of their research with the scientific community, thereby enhancing the scope and influence of their work. With publications, researchers can publish new findings, gain input from peers, and develop their reputation in a particular subject. In addition, publications can serve as a standard for measuring academic production and aid in submitting new research projects. Hosting scientific journals on the institutional side can bolster academic prestige and global recognition. Institutions with esteemed publications can allure a more significant number of researchers and students, enhance their reputation among the general public, and get more resources through journal subscriptions or external research funding. Scientific publications offer enduring advantages to researchers and institutions engaged in the process.

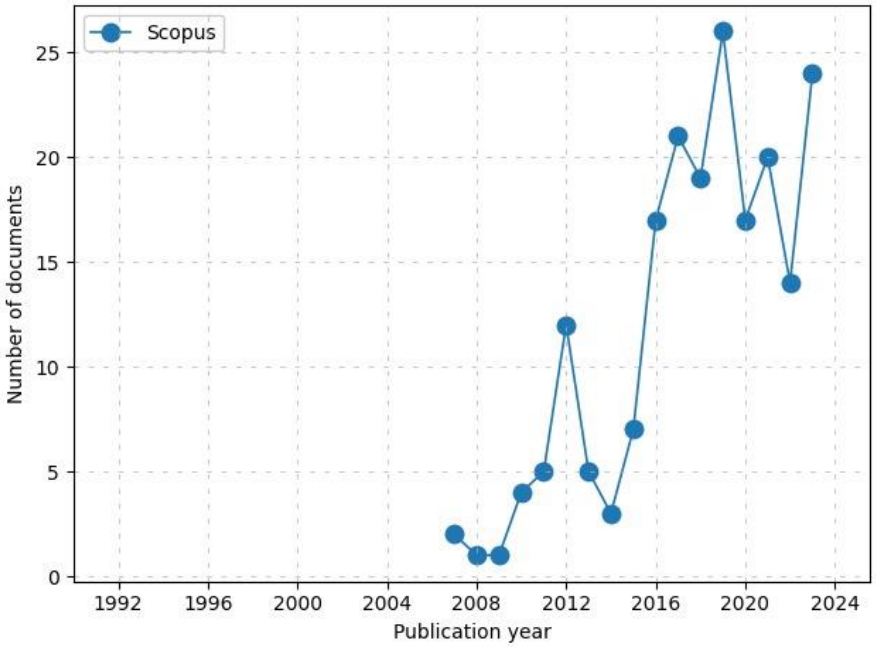

Figure 1 Database Timeline

Figure 1 shows a significant rise in research activity in this field during 32 years from 1990 to 2023. There has been a notable rise in the number of entries and research output, especially between 1990 and 2013, reaching a peak in 2019 with 26 entries. This trend highlights the significant progress in research output in the discipline, especially in mobile learning in mathematics education. The growth demonstrates a substantial expansion and development in research databases within the defined period. The indicators show that research in this field is receiving attention and acknowledgement, highlighting its importance and contribution to the broader academic discussion. The study's findings indicated that 74.1% of students preferred using mobile dictionaries over printed resources for learning purposes (Başaran, 2022). (Başaran, 2022) 54.5% of respondents reported that mobile learning

contributed to their ability to retain knowledge and achieve achievement, while 47.1% believed mobile applications were more advantageous. The number of entries consistently rises yearly, indicating the progressive expansion or advancement of the themes shown in this timeline.

There has been a notable rise in publications from 2007 to 2023, with minor declines in 2020 and 2022 that need to be more statistically relevant. In 2019, there was a significant increase in growth, reaching 26 documents. This study demonstrates an exponential rise in the number of articles included in Scopus from 1990 until at least 2023. Yearly variations in the number of papers included in indexes indicate shifts in academic publishing trends influenced by technological advancements.

Databases like Scopus are crucial for gathering and analysing data on publishing trends, aiding in comprehending shifts in the worldwide science system. Scopus is now the most extensive collection of abstracts and citations for peer-reviewed research literature, offering valuable tools for analysing trends in the scientific field through bibliometric studies.

3.1.2 The Document Types

The primary focus of this research is the first descriptive category, referred to as "Document type". An examination of this particular document reveals the various sorts and characteristics of mobile learning mathematics documents. Gaining comprehension of these documents enables us to utilise multiple informational sources and track their development and patterns. Gaining a more comprehensive understanding of these categories can assist in directing future research and enhancing the incorporation of mobile technologies in mathematics learning environments.

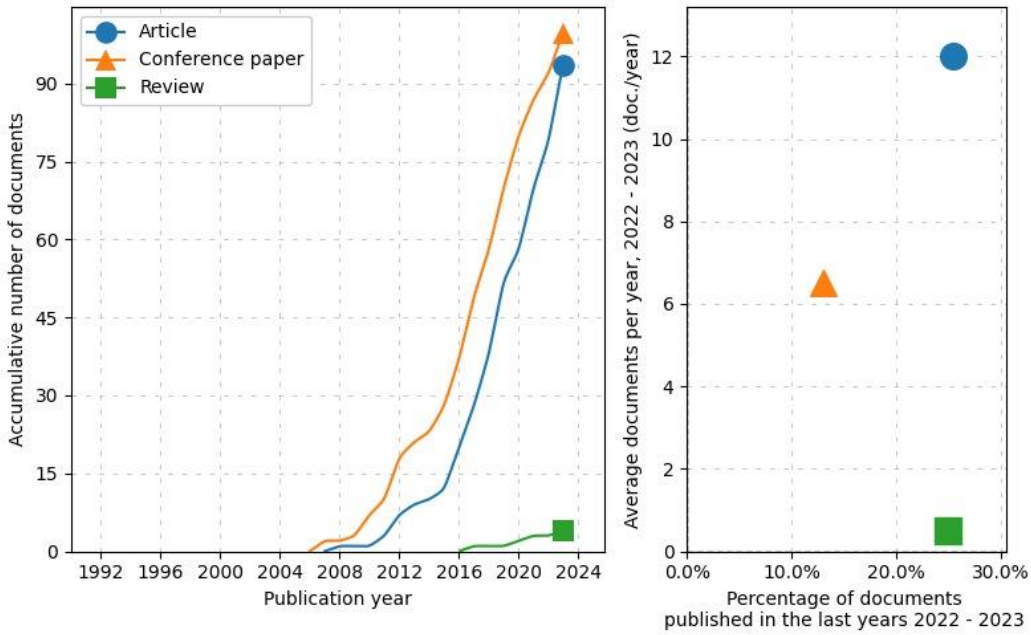

Figure 2 Document Types

Analysis indicates a consistent growth of conference papers (50.50%) year, with the most significant increases observed in 2017 and 2019, totalling 12 articles. This highlights the significance of conferences for sharing information and fostering collaborative learning. Academic conferences play a crucial role in sharing new research findings and facilitating discussions on innovative ideas in many areas of higher education (Wilton et al., 2022). Articles (47,47%) demonstrate a notable annual growth, with the most substantial rise occurring in 2023, highlighting the crucial role of articles in scientific publishing. This article introduces a scientific writing task that aims to facilitate the spread of precise and reliable information (Muchira, 2023; Riser et al., 2020). Reviews demonstrate a lower growth rate

than conference papers and articles. However, they exhibit an upward trend, highlighting their significant function in offering summaries and analyses of current literature.

An upward trend in the number of publications indexed by Scopus is evident, with the most significant growth observed in conference papers in 2019 and articles in 2023. This demonstrates the substantial advancement in research and education, highlighting the crucial role of databases like Scopus in gathering and examining publication data. Evaluate the quality and dependability of the database papers. While the figures may be substantial, it is essential to consider study methodologies, the data's precision, and the sources' integrity. Reviews can aid you in selecting the optimal and most pertinent research books. This timeline database can be advantageous for researchers in various disciplines. To further research and scientific progress, it is crucial to analyse publishing patterns, research subjects, and the quality of documents. Researchers must utilise this data judiciously and analytically.

3.1.3 Classification of Analysis Based on Detailed Description

The country is the second category used to describe this inquiry. Countries are analyzed to determine their geographical distribution and impact on mobile mathematics education. Analyzing the contributions made by various countries in mobile technology research and development in mathematics education allows us to identify and understand trends and patterns. Gaining insight into the respective contributions of different countries in this development enables us to formulate targeted recommendations and strategies for the global expansion of mobile learning in mathematics.

These countries, including Indonesia, the United States, and Malaysia, demonstrate a high capability for generating scientific papers, indicating the quality and quantity of research conducted by their scientific organisations. These nations can create substantial publications that enhance knowledge and innovation across several disciplines.

Table 2. An order of the most productive nations

Country	Total	AGR	ADY	PDLY
Indonesia	16	-0,5	1,5	18,8
United States	13	-0,5	1	15,4
Malaysia	12	1	2,5	41,7
South Africa	11	0	0	0
Philippines	10	0,5	1	20
Taiwan	10	0	0	0
Turkey	10	0	2	40
Portugal	8	1,5	2,5	62,5
Sweden	8	0	0	0
Germany	7	1	2,5	71,4
Spain	7	0	0,5	14,3
Australia	6	0,5	0,5	16,7
Brazil	6	0	0	0
Slovakia	6	0	0	0
United Kingdom	5	1	1	40

South Africa, a leading gold producer globally, is facing significant challenges in mining productivity. Despite being in a better situation than China, South Africa's productivity lags significantly behind that of countries like Australia and the United States. South Africa needs help enhancing its production, which may affect its capacity to generate substantial scientific publications. This situation

highlights the significance of resource management and infrastructure investment in improving research productivity and quality.

3.1.4 An Analysis of The Keyword Lists Employed by The Authors

During scientific study, authors frequently employ keywords relevant to the field, subfield, topic, and specific area of research interest. Keywords have a crucial role since they enable other researchers to search for topics relevant to their interests effectively. Researchers can efficiently locate publication venues that are pertinent and valuable for their research by employing appropriate (Gande et al., 2024; Punithavili Mariappan et al., 2024; Widad Ma et al., 2024). Furthermore, these keywords also enhance the prominence and availability of scientific articles, facilitating the spread of knowledge and cooperation among researchers in specific research areas. Hence, meticulous and pertinent use of keywords is a crucial tactic for authors of scientific publications to enhance the influence and worth of their research.

This study aims to examine and explain the ten most often occurring index keywords in different scientific papers. This research seeks to enhance comprehension of research trends and concentration within a specific topic or subfield by examining authors' most commonly employed keywords. Hence, the data acquired from this study might furnish researchers with an invaluable understanding of the pivotal or prevalent subjects in contemporary scholarly publications. Furthermore, examining the keywords top writers use can offer valuable knowledge of the evolution and shifts in research trends over time. This research provides a comprehensive understanding of the research topic and adds to a broader comprehension of the scientific and developmental processes within the subject of study.

The primary emphasis of this study is the keyword index, which is the initial descriptive category. Through examining this keyword index, we may identify and acquire knowledge about the most often occurring keywords in the literature about the utilisation of mobile devices for mathematical learning. It provides a comprehensive overview of the primary fields of study and current research patterns in this domain. Over time, we can discern the evolving trends and advancements in popular concepts and methodologies by having extensive knowledge of the keyword index. This enables us to strategise and undertake future studies that are more comprehensive and beneficial. It is advantageous to devise improved integration techniques to enhance the quality of mathematics education using mobile technology.

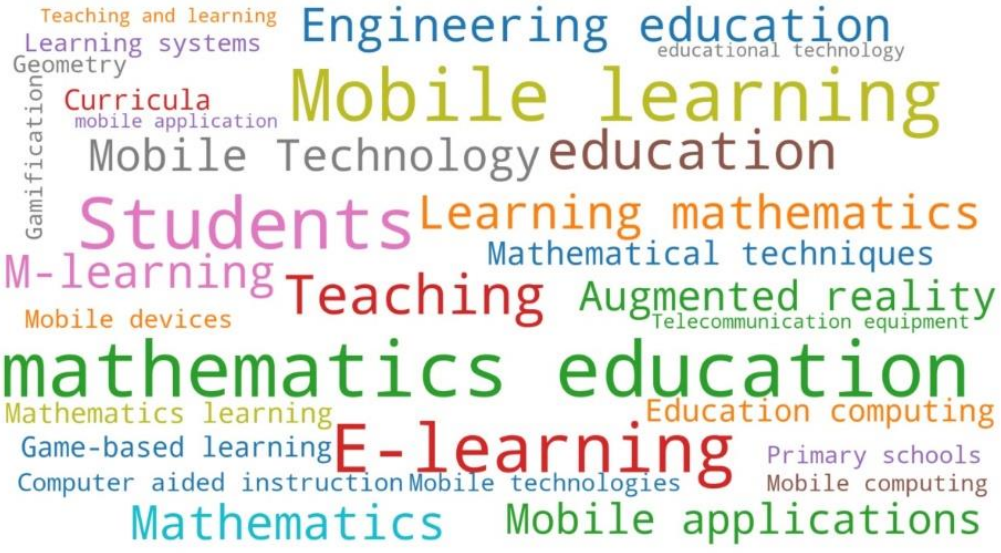

Figure 3 Index keyword

An analysis of the terms "mathematics education" and "mobile learning" shows a significant rise in frequency between 1990 and 2023. This rise highlights the importance of mobile technology in mathematics education, a subject of interest in research and scholarly publications. Due to the growing number of publications, mobile learning in mathematics is gaining importance in modern education. The growth in publishing was especially significant in 2019 and 2020, suggesting a peak in efforts to apply and evaluate this technique in education.

The increase in the use of mobile technology in mathematics education is associated with advancements in education and increased participation of both students and teachers. These findings demonstrate the enhancement of student learning and teaching effectiveness using interactive and technology-driven methods. The increasing usage of mobile technology in a mathematical environment and education is evident from the growing popularity of terms like "E-learning." This trend highlights mobile technology's significant role in transforming modern education.

3.2. Discussion

Enhancing student comprehension and involvement is a top priority in mathematics education by integrating mobile technologies. Utilising mobile applications and platforms designed for interactive mathematics learning can assist in achieving this objective. These apps help augment students' learning through interactive activities (Apostolidis et al., 2024; Grinder et al., 2024; Hwang et al., 2024; Tho et al., 2023), visual simulations (Adiuku et al., 2024; Bezerra et al., 2024; Moon et al., 2024; Park et al., 2024), and arithmetic games (Bringula et al., 2023; Çakır et al., 2016; Cerratto Pargman et al., 2018; Phan et al., 2024; Vishnoi et al., 2023). Mobile learning enables students to learn autonomously and personalise their learning experience. It can also facilitate professors' providing prompt feedback, assigning assignments, and fostering student collaboration through discussion boards and virtual classes. Utilising mobile technology in mathematics can enhance student motivation, engagement, and comprehension of the subject matter.

Developing math-learning mobile apps and platforms is essential for enhancing education (Hatzipanagos & John, 2017; Pombo, 2023; Zuhaili et al., 2023). This application and platform provides comprehensive support for students and teachers, offering many features to enhance the learning experience. The package includes interactive activities, visual simulations, educational films, adaptive tests, and discussion forums. Additionally, these applications possess reporting capabilities that enable professors to monitor student advancement and offer feedback. The promise of mobile technology is significant, although both students and teachers have difficulties utilising it. The adoption of mobile technology in mathematics learning can be influenced by technological infrastructure (Murire & Cilliers, 2019), proficiency in using the technology (Alkhawalde & Khasawneh, 2024; Koleini et al., 2024; Peng et al., 2024), support from schools or institutions (Donohue & Aladé, 2024; Masadeh et al., 2024), and belief in its effectiveness (Chang et al., 2021; König & Suhr, 2023; Olić Ninković et al., 2022; Prabhakar & Veena, 2023). Hence, mobile application and platform developers must consider these factors during product development to enhance technology acceptance and adoption.

The effectiveness of mobile-based mathematics learning relies on the approaches used for evaluation (Niromand et al., 2024; Riko Arrasyid et al., 2024) and performance (Asadchykh et al., 2024; Farah, 2024; Lah et al., 2024) measurement. To evaluate student comprehension, engagement, and learning goals, it is necessary to develop appropriate assessment methods. The instrument should demonstrate problem-solving proficiency, understanding mathematical concepts, and applying mathematics in real-world situations. Furthermore, thoroughly examining data is crucial for comprehending evaluation results and pinpointing areas for enhancing the learning process. Statistical analysis, student progress mapping, and trend analysis can aid educators and politicians in making facts-based decisions. Educators may optimise mobile-based mathematics instruction's benefits and learning capacity by employing practical assessment and evaluation techniques.

Suggestions for further advancement include enhancing collaboration among researchers, educators, and practitioners to devise mathematics teaching methodologies based on mobile learning. This collaboration has the potential to expedite the adoption of innovations and create new possibilities for exploring how mobile technology might be more efficiently incorporated into the mathematics curriculum. Furthermore, addressing the disparity in research contributions between developed and developing nations is imperative to guarantee fair and equal access to mobile technology in diverse educational settings. By engaging in cross-border collaboration and inclusive initiatives, we can maximise the efficacy of mobile learning in enhancing students' comprehension and performance in mathematics education.

4. Conclusions

A study examining the progress of publications on mobile learning in mathematics education reveals good patterns in the investigation and use of mobile technology in educational settings. The upward trajectory of articles over time indicates that mobile learning has transitioned from a fad to a central focal point in advancing mathematics education. The significance of keywords like "students," "engineering," "e-learning," "education," and "teaching" indicates the broadening of the use of mobile learning, encompassing not only student experience but also its interaction with engineering and related disciplines.

Incorporating technology has a significant prospect for enhancing student comprehension and involvement. Creating applications and platforms designed expressly for mathematics education can be a successful approach to addressing the requirements of students and teachers while considering the elements that impact the acceptance of this technology. Furthermore, using assessment methods and performance measurement is crucial in guaranteeing the efficacy of learning. This involves creating suitable evaluation tools and conducting meticulous data analysis to comprehend learning outcomes comprehensively. Therefore, this research offers valuable knowledge for creating advanced and efficient mathematics teaching methods through mobile technology.

Conflict of Interest

The authors declare no conflicts of interest.

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