TẠP CHÍ KHOA HỌC
TRƯỜNG ĐẠI HỌC SƯ PHẠM TP HỒ CHÍ MINH

Tập 22, Số 3 (2025): 487-499

Website: https://journal.hcmue.edu.vn

ISSN: 2734-9918

HO CHI MINH CITY UNIVERSITY OF EDUCATION
JOURNAL OF SCIENCE

Vol. 22, No. 3 (2025): 487-499

https://doi.org/10.54607/hcmue.js.22.3.4457(2025)

Research Article

A SYSTEMATIC REVIEW OF MOBILE LEARNING IN MATHEMATICS EDUCATION: GLOBAL AND VIETNAMESE PERSPECTIVES FROM 2008 TO 2024

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Received: September 06, 2024; Revised: October 16, 2024; Accepted: October 18, 2024

ABSTRACT

The rapid advancement of mobile technology over the past two decades has significantly impacted education. Along with this progress, a new form of learning known as mobile learning (m-learning) has emerged. Over the years, many studies on m-learning in mathematics education have increased significantly. This research is a systematic review of 43 international articles and five studies from Vietnam related to mobile learning in mathematics education from 2008 to 2024. The study aims to answer questions regarding the purposes, methods, results, applications, websites, mathematical content, learning locations, and mobile devices used in m-learning studies in mathematics education. The research presents findings based on these questions, particularly highlighting gaps in the existing studies on this topic both internationally and in Vietnam. This review provides valuable insights for educators and researchers interested in integrating mobile learning into mathematics education and identifies key areas for future research.

Keywords: mathematics education; m-learning; mobile device; mobile learning; mobile technology

1. Introduction

Over the past two decades, rapid advancements in mobile technology have significantly impacted various aspects of education. Consequently, mobile learning (m-learning) has emerged as a promising educational approach that leverages mobile devices' ubiquity, portability, and connectivity to enhance students' learning experiences. According to UNESCO (2013, p.6):

> Mobile learning involves using mobile technology alone or with other information and communication technology to enable learning anytime and anywhere. Learning can unfold in various ways: people can use mobile devices to access educational resources, connect with others, or create content, both inside and outside classrooms. Mobile learning also encompasses efforts to support broad educational goals such as the effective administration of school systems and improved communication between schools and families.

Cite this article as: Do, P. N. K., & Tang, M. D. (2025). A systematic review of mobile learning in mathematics education: Global and Vietnamese perspectives from 2008 to 2024. *Ho Chi Minh City University of Education Journal of Science, 22*(3), 487-499. https://doi.org/10.54607/hcmue.js.22.3.4457(2025)

Mobile learning offers substantial educational benefits, including flexibility and convenience, allowing students to learn at their own pace, anytime and anywhere (Crompton, 2013). It enhances student motivation and engagement through interactive tools and gamification (Criollo-C et al., 2021; Gikas & Grant, 2013). Furthermore, mobile learning has been shown to improve learning outcomes by providing diverse and personalized learning methods (Sung et al., 2016). Since its inception, mobile learning has garnered significant attention from researchers across various fields, with mathematics education being one of the most studied areas (Crompton et al., 2017). Most studies indicate that mobile learning positively impacts students' learning outcomes, such as enhancing their understanding of mathematical concepts through interactive tools and applications, developing skills like problem-solving, and applying knowledge to real-world contexts (Al-Khateeb, 2018; Fessakis et al., 2018; Hwang et al., 2020; Larkin & Calder, 2016; Li et al., 2022). Studies on mobile learning in mathematics education have increased over the years (Criollo-C et al., 2021; Crompton & Burke, 2017, 2020; Lai, 2019; Tang et al., 2023). In this context, reviewing mobile learning in mathematics education is crucial to identify achieved outcomes and research gaps, thereby suggesting future research directions.

Previous reviews on mobile learning in mathematics education have provided valuable insights. However, they are often limited by publication timeframes, search strategies, and research questions. The most recent review by Tang et al. (2023) covers studies from 2008 to 2021. Nevertheless, numerous studies on mobile learning in mathematics education have been published in the subsequent three years. Additionally, a review has yet to assess the research landscape in Vietnam. Therefore, updating the review on this topic is essential.

Our study focuses on synthesizing articles related to mobile learning in mathematics education, both domestically and internationally, from 2008 to 2024 as an extension of Tang et al. (2023), who reviewed studies on mobile learning in mathematics education published between 2008 and 2021. The following questions will guide the research:

1. In studies related to mobile learning in mathematics education, what were the major research purposes, methodologies, and outcomes?
2. In studies related to mobile learning in mathematics education, which mathematical content was studied?
3. In studies related to mobile learning in mathematics education, what applications, websites, and mobile devices were used?
4. In studies related to mobile learning in mathematics education, what were the learning locations?
5. What were the key findings in studies related to mobile learning in mathematics education in Vietnam?

2. Method

2.1. Search Strategy

Our literature collection process involved conducting electronic searches across multiple databases. We searched Springer, ScienceDirect, Taylor & Francis, Emerald Insight, SAGE journals online, ProQuest, JSTOR, and Google Scholar for English databases.

For Vietnamese databases, we searched the highest-scored domestic journals listed by the 2024 Professor Council for the Educational Sciences, Vietnam Journals, and Google Scholar. The search was divided into two main parts: searching in Vietnamese and English. For the English search, we used terms related to mathematics such as "mathematics," "math," "learning mathematics," "teaching mathematics," "algebra," "calculus," "geometry," "probability," and "statistics," combined with terms related to mobile learning such as "mobile learning," "m-learning," "mobile device," "mobile technology," "mobile phone," "Ipad," "tablets," and "smartphone." Similarly, these terms were translated into Vietnamese and used for the search. These search terms were selected because they frequently appear in descriptions of mobile learning in mathematics.

2.2. Inclusion/Exclusion Criteria

To select appropriate studies, we used the PRISMA 2020 diagram, which includes the stages of identification, screening, and inclusion (Figure 1) (Page et al., 2021). The studies are required to meet all the inclusion and exclusion criteria in Table 1. These criteria were adapted from Crompton and Burke (2017) and Tang et al. (2023) to suit this study's research context.

Table 1. *Inclusion and Exclusion Criteria*

Inclusion Criteria	Exclusion criteria
Mobile learning in mathematics education	Not specific to mathematics education
Empirical research	Review research
Original research	Thesis
Published between 2008 and 2024	Chapter/section of the book
	Mobile devices must not be laptops
	Mobile devices must not be netbooks
	Mobile devices must not be calculators
	Participants are not K-12 students

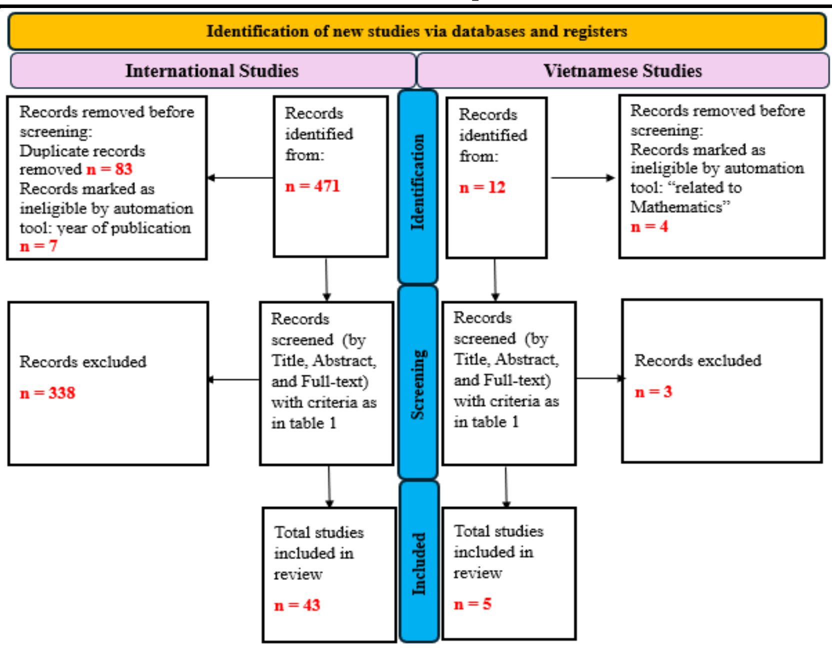

Figure 1. *PRISMA 2020 flow diagram* (Source: Authors' own elaboration)

2.3. Analysis Strategy

International Studies: Data were extracted from 43 research papers on mobile learning in mathematics education, published in international journals and selected based on the established criteria (Table 1). Each study was reviewed using a standardized data extraction form with the following categories: 1) Research purpose, (2) Research methodology, (3) Research outcomes, (4) Mathematical content, (5) Applications or websites used, and (6) Mobile devices (e.g., smartphones, tablets) and learning environments (e.g., classroom, outdoor, or hybrid settings). The data were then synthesized based on these six categories to present the research findings.

Research purposes are divided into the following four categories: (1) evaluating the impact of mobile learning on students' mathematics achievement, (2) investigating the effectiveness of mobile applications/websites in teaching mathematics, (3) exploring students' perceptions of mathematics learning through mobile learning, and (4) examining the ways mobile devices support learning activities. Research methods are coded into three main types: qualitative, quantitative, and mixed. The applications and websites are divided into two categories: the first type is designed by the researchers themselves, while the second type utilizes existing applications and websites. The mathematical content studied in the literature is classified into four main areas: algebra and arithmetic, analysis, probability - statistics, and geometry. The research results will be coded into positive, negative, neutral, and other.

Vietnamese Studies: Given the limited number of studies on mobile learning in mathematics education in Vietnam (only five studies), we analyzed and reported the outcomes of each study individually, focusing on its specific context, methodology, and outcomes.

3. Results

3.1. Research Purposes

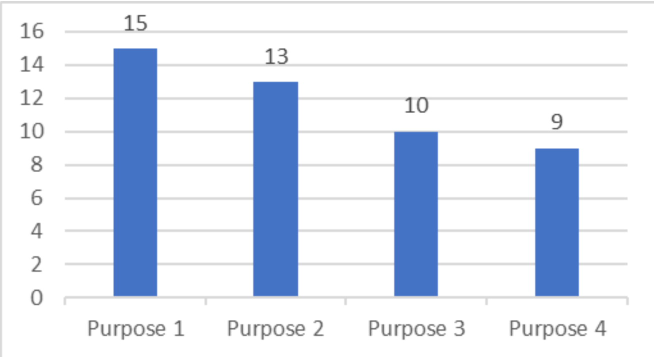

Figure 2. *Research purposes of studies (Source: Authors' own elaboration)*

Our analysis and synthesis of research on mobile learning in mathematics education revealed four main research purposes: (1) evaluating the impact of mobile learning on students' mathematics achievement, (2) investigating the effectiveness of mobile applications/websites in teaching mathematics, (3) exploring students' perceptions of mathematics learning through mobile learning, and (4) examining the ways mobile devices support learning activities. Among these, the primary research focus of most studies was purpose (1), evaluating the impact of mobile learning on students' mathematics achievement, which is understandable given the increasing prevalence of mobile learning and the importance of assessing its influence on student performance. The remaining purposes were also categorized based on their frequency in the literature.

3.2. Research Method

In Figure 3, quantitative research methods are the most frequently used, appearing in 16 studies, followed by mixed methods, used in 15 studies. Qualitative research methods are the least utilized, with only 12 studies. The trend has shifted toward declining qualitative methods in recent years, while quantitative and mixed methods have become more popular.

These methodologies' primary data collection tools include pre-/post-tests, self-report measures, interviews, observations, and open-ended questionnaires. Among these, pre-/post-tests are the most commonly used tools, primarily to assess the impact of mobile learning on students' mathematics achievement (the main research purpose in most papers). Self-report measures are the second most utilized tools, often conducted through survey questionnaires based on a 5-point Likert scale, allowing for the collection of structured quantitative data on participants' opinions, perspectives, and attitudes towards significant variables. Conversely, data collection using open-ended questionnaires focuses on gathering written responses, facilitating a deeper understanding of students' experiences.

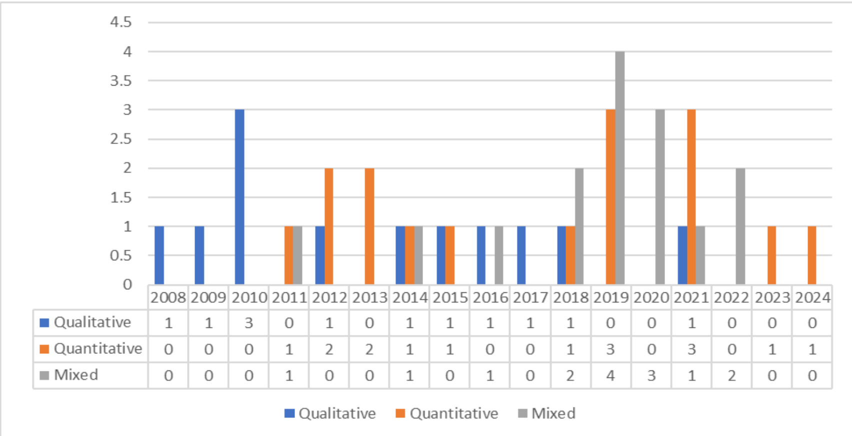

Figure 3. *Publication distribution by research methods over the years (Source: Authors' own elaboration)*

3.3. Research Outcomes

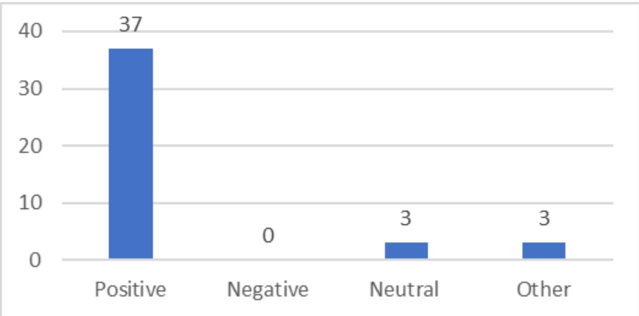

Figure 4. *Attitude of outcomes in mobile learning (Source: Authors' own elaboration)*

The majority of studies (37 studies) had positive results, many showing that students' mathematics achievement improves with mobile learning. The results also suggest that using augmented reality (AR) applications, mathematical games, and educational websites enhances students' mathematical understanding and creates stimulating and engaging learning environments. Additionally, student and teacher engagement and satisfaction with mobile applications and websites are high, with many considering them valuable tools in the mathematics learning process.

No studies reported negative results. Three studies showed neutral outcomes, with no difference in results before and after the intervention, or where further research is needed to clarify the impact better. The studies with other outcomes focused on surveys of students' perceptions.

However, implementing mobile learning in mathematics education presents challenges such as accessibility, content quality, and affordability. These issues are particularly crucial in regions with poor technological infrastructure and limited educational resources. Furthermore, ensuring the appropriateness and effectiveness of mobile applications and websites requires investment in research and development from educators and software developers.

3.4. Mathematical Content

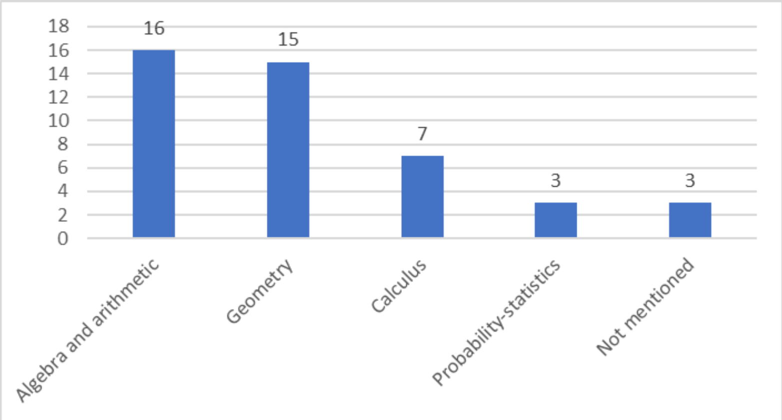

Figure 5. *Distribution of studies by mathematical content*
(Source: Authors' own elaboration)

The mathematical content studied in the literature primarily revolves around four main areas: algebra and arithmetic, calculus, probability - statistics, and geometry. Algebra and arithmetic are the most frequently studied, encompassing algebraic expressions, solving equations, inequalities, and algebraic rules. Other algebraic content, such as trigonometry, sequences, geometric progressions, and arithmetic progressions, is also examined in several studies.

Next is geometry, where research focuses on plane and spatial geometry. The study of plane geometry often involves content related to the area and perimeter of basic shapes like triangles, squares, rectangles, parallelograms, rhombus, trapezium, and circles. Additionally, understanding angle measurement and symmetry are prominent topics. Spatial geometry extends the research scope to three-dimensional shapes like rectangular prisms, cubes, cylinders, and spheres. Content such as space coordinate systems, spatial relationships between lines and planes, and spatial intersections among shapes is also mentioned in research works.

Finally, calculus, probability, and statistics appear less frequently. Probability-statistics is the least studied, appearing in only three research papers. It typically focuses on information processing, recognizing probability concepts, and the relationship between experimental and theoretical probability. Calculus content primarily investigated includes functions and graphs, slopes, and integration.

3.5. Applications and Websites Used

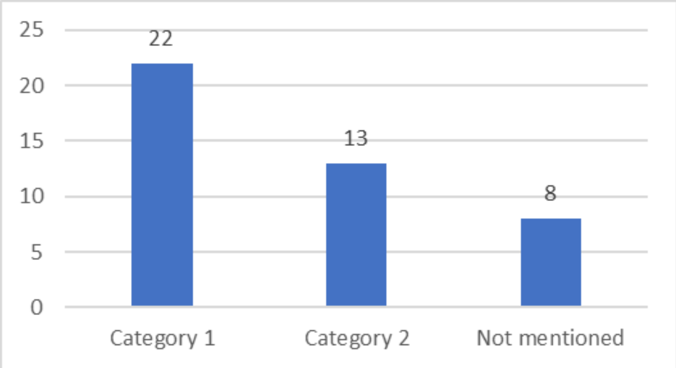

Figure 5. *Apps and websites used in studies (Source: Authors' own elaboration)*

The studies reviewed utilized various applications and websites for learning mathematics, which can be categorized into two types. The first type includes applications and websites designed by the authors of the papers, which were then tested to measure their effectiveness and impact on students' mathematics achievement. These applications often involve augmented reality (AR) technology or games using mathematical knowledge. The websites are typically designed as e-learning systems where students can access the site to select learning content, engage in tasks, receive hints if they struggle, take tests after each learning module, and get feedback from peers and teachers through a discussion feature. Some websites also incorporate games that require students to solve problems related to their mathematics studies to progress. This first type is recorded in more than half of the studies.

The second type includes readily available mobile or internet-based applications and websites that students can directly use online or download to complete tasks assigned by their teachers. Notable applications include Sketchpad Explorer, Cabri 3D, GeoGebra, Google Maps, and Camera (for capturing images and recording real objects during learning). Additionally, websites like PhET (https://phet.colorado.edu) Interactive Simulations provide interactive science and mathematics simulations, GeoGebra (https://www.geogebra.org) offers free mathematics software for calculations, graphing, and geometric and algebraic operations, and Math4Mobile (https://www.math4mobile.com) provides mobile applications and learning resources for mathematics.

3.6. Types of Mobile Devices

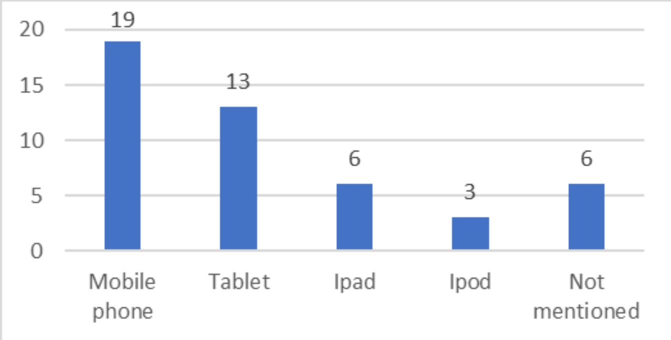

Figure 6. *Types of mobile devices used in research (Source: Authors' own elaboration)*

Smartphones are the most commonly used devices in studies, with 19 research articles highlighting their use, followed by tablets (13 studies), iPads (6 studies), and iPods (3 studies). Some studies do not specify the mobile devices used, or in some cases, no mobile devices are involved at all, as these studies are primarily survey-based. It is important to note that not all research focuses on a single type of mobile device – some studies utilize multiple devices simultaneously. During the experimental phase, these devices can either be the students' personal devices or provided by the researchers.

3.7. Learning Locations

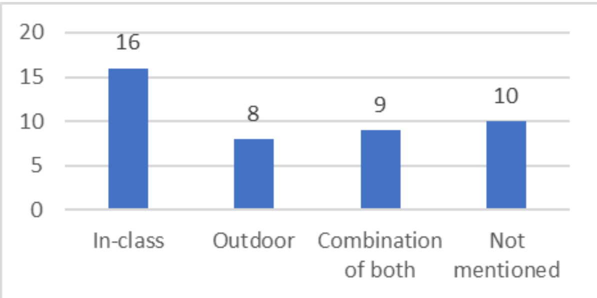

Figure 7. *Learning locations in studies (Source: Authors' own elaboration)*

The learning locations in studies involving mobile learning in mathematics education can be classified into three main types: in-class, outdoor, and a combination of both. Although the devices allow for mobility, most studies (16 research papers) take place in the classroom, where students primarily use mobile devices to access applications supporting task completion or participate in online learning systems prepared by teachers. Nine studies combined in-class and outdoor learning, while eight studies took place outdoors. Most outdoor activities involve using real-world data, such as measuring the height of actual objects or calculating the area of real-world items. However, the tasks proposed in these studies often need more real-world context, focusing mainly on using formulas for calculations.

3.8. Research in Vietnam on Mobile Learning in Mathematics Education

Vietnamese mathematics educators have started integrating these devices into teaching processes in the context of increasing mobile device popularity. The term "mobile learning" (m-learning) has gained significant attention in Vietnam. In her thesis, Trinh (2014) clarified the positive benefits of mobile learning, including using mobile phones for self-study in grade 12 mathematics. The study proposed a mobile learning model with functions suitable for student self-study, identified steps for implementing mobile learning, and outlined specific requirements and principles for developing electronic learning materials to support grade 12 mathematics self-study. The study suggested exploiting certain mobile applications to assist students in self-studying mathematics both in and out of class. The conclusions indicated that implementing mobile learning in Vietnam is feasible.

From 542 student responses and 40 teacher responses in two surveys, Trinh et al. (2019) found that Vietnamese students need help with mobile learning due to issues accessing mathematics websites, low content quality, poor self-study skills, and lack of interest. Also, based on the TAM model, Le et al. (2021) researched factors affecting Vietnamese students' decisions to use M-learning. Analysis of 238 survey samples showed that to encourage M-learning usage, educators should focus on designing suitable courses to save time, improve learning efficiency, increase learner flexibility, and promote course convenience through various channels.

Le and Tran (2021) studied factors influencing 285 mathematics teachers' acceptance of smartphones in teaching at secondary schools in Binh Duong and Ho Chi Minh City. The study, which used a simple linear regression model, analyzed the impact of variables such as confidence in using teaching software, perceived feasibility of teaching software, and gender on smartphone acceptance. Results showed that all three factors influence smartphone acceptance, with male teachers and those more confident in using software being more accepting.

Recently, Le et al. (2024) investigated the effectiveness of the Microsoft Math Solver (MMS) application in enhancing Grade 8 students' self-study skills when solving linear equations. Conducted over two weeks with an experimental group using MMS and a control group following traditional methods, the study found that the MMS group performed significantly better. Analysis of student worksheets revealed that the experimental group had a deeper understanding of linear equations and effectively used MMS to support their learning process. The study concluded that mobile learning with MMS could effectively enhance students' self-study competency and significantly improve academic performance in linear equations under the 2018 Mathematics Curriculum in Vietnam.

4. Conclusion

This study aims to review and evaluate research on mobile learning in mathematics education from 2008 to 2024, focusing on international and Vietnamese contexts. The results provide insights into the purposes, methods, outcomes, mathematical content, applications and websites, learning locations, mobile devices used in global studies, and key findings from Vietnamese research.

The findings indicate that most research focuses on assessing the impact of mobile learning on students' academic performance and the effectiveness of mobile applications and websites in teaching mathematics. The studies predominantly employ quantitative and mixed methods, with an increasing number of studies combining both quantitative and qualitative approaches. Most research results indicate positive effects of mobile learning on students' mathematics achievement. Our findings align with previous reviews, such as those by Crompton and Burke (2017) and Tang et al. (2023), which also highlight the primary focus on the impact of mobile learning on student performance. However, our study extends the timeline to 2024 and includes recent studies showing a growing interest in the potential benefits of mobile learning.

The research reveals a diversity in the use of applications and websites for learning mathematics. Recent studies highlight advanced technologies like augmented reality (AR) and game-based learning, which have been shown to enhance students' understanding of mathematical concepts and increase student engagement (Hwang et al., 2020; Li et al., 2022). The complexity and variety of mobile learning tools are increasing. Learning locations are also diverse, including both classroom and outdoor settings, depending on the research objectives and the features of the applications or websites used. Mobile devices such as smartphones and tablets (iPads, iPods) have enhanced students' "mobility" in learning. In some studies, researchers provide mobile devices directly during the experimental process. This raises a critical consideration when implementing mobile learning for mathematics in actual classroom environments: whether enough devices are available for all students. When designing mathematical learning activities incorporating mobile learning, teachers must carefully assess the number of devices required to ensure successful implementation. The distinction between students' personal devices and those provided by researchers highlights an important variable in experimental design, potentially affecting outcomes based on the users' familiarity with and access to the devices.

The mathematical content studied in mobile learning research primarily includes algebra and arithmetic, followed by geometry, and finally, calculus and probability-statistics. However, the studies do not always clearly define these mathematical topics. Many studies on mobile learning do not focus on specific mathematical content but rather cover multiple areas, such as arithmetic, measurement, geometry, and probability-statistics, as Yeh et al. (2019) exemplify. This finding is consistent with Crompton and Burke (2017).

Despite the positive outcomes reported in many studies, our review identified several challenges and gaps in the current research. A notable issue is the contextualization of learning tasks. While some studies incorporate real-world objects and scenarios, many tasks still lack real-world context, focusing instead on theoretical problems like calculating height, perimeter, area, and drawing figures. This limitation reduces students' ability to develop practical problem-solving skills. Another significant gap is the underrepresentation of studies on spatial geometry in outdoor learning contexts. While planar geometry often benefits from real-world data collection, spatial geometry offers similar, if not greater, opportunities for practical application and the development of spatial reasoning skills.

Numerous studies have shown that mobile learning can enhance students' mathematical competencies, such as mathematical problem-solving skills (Al-Khateeb, 2018; Amin et al., 2021) and mathematical modeling competence (Cahyono et al., 2020; Daher, 2010). Additionally, we found that mobile devices provide various tools that support students' learning in mathematics, such as geometry software, graphing tools, and automated problem-solving platforms. These tools can potentially foster aids and tools competency in learning mathematics. However, none of the studies on mobile learning in mathematics education in Vietnam that we reviewed addressed this aspect. Only two studies proposed specific scenarios for teaching mathematics through mobile learning, with one focusing on the knowledge objectives of the 2018 Mathematics Curriculum and the general competencies outlined in the 2018 General Education Program.

Our study provides an overview of mobile learning research in mathematics education from 2008 to 2024, highlighting both global trends and specific findings in Vietnam. Despite these advancements, challenges such as accessibility, content quality, and affordability persist, particularly in areas with limited technological infrastructure. Furthermore, the need for context-based learning tasks and real-world applications remains a significant area for further research. In Vietnam, the number of studies on mobile learning in mathematics education is still limited, indicating a need for more focused research on leveraging mobile learning to enhance mathematical competencies, according to the 2018 Mathematics Curriculum. While mobile learning offers promising opportunities, addressing these challenges will be crucial for effectively implementing this approach in mathematics education.

❖ ***Conflict of Interest:*** *Authors have no conflict of interest to declare.*

❖ ***Acknowledgments:*** *This research is funded by Ho Chi Minh City University of Education Foundation for Science and Technology under grant number CS.2024.19.78.*

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TỔNG QUAN HỆ THỐNG VỀ HỌC TẬP DI ĐỘNG TRONG GIÁO DỤC TOÁN HỌC: GÓC NHÌN TOÀN CẦU VÀ VIỆT NAM TỪ NĂM 2008 ĐẾN 2024

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Ngày nhận bài: 06-9-2024; ngày nhận bài sửa : 16-10-2024; ngày duyệt đăng: 18-10-2024

TÓM TẮT

Sự tiến bộ nhanh chóng của công nghệ di động trong hai thập kỉ qua đã ảnh hưởng đáng kể đến giáo dục. Cùng với sự tiến bộ đó, một hình thức học tập mới ra đời, được gọi là "học tập di động" (mobile learning hay m-learning). Qua các năm, số lượng nghiên cứu về học tập di động trong Giáo dục Toán học tăng đáng kể. Nghiên cứu này là một tổng quan hệ thống của 43 bài báo quốc tế và 5 công trình nghiên cứu ở Việt Nam liên quan đến học tập di động trong Giáo dục Toán học giai đoạn 2008-2024. Nghiên cứu nhằm mục đích trả lời các câu hỏi về mục đích, phương pháp, kết quả, ứng dụng, trang web, nội dung toán học, địa điểm học tập, thiết bị di động được sử dụng trong các nghiên cứu về học tập di động trong Giáo dục Toán học. Nghiên cứu trình bày những phát hiện dựa trên việc trả lời câu hỏi nghiên cứu, đặc biệt nó chỉ ra các khoảng trống trong các nghiên cứu hiện có về chủ đề này trong bối cảnh quốc tế và Việt Nam. Đánh giá này cung cấp những hiểu biết có giá trị cho các nhà giáo dục và nhà nghiên cứu quan tâm đến việc tích hợp học tập di động vào giáo dục toán học và xác định các hướng quan trọng để tiếp nối nghiên cứu trong tương lai.

Từ khoá: Giáo dục Toán học; m-learning; thiết bị di động; học tập di động; công nghệ di động