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Review Article

Using m-learning in teacher education: A systematic review of demographic details, research methodologies, pre-service teacher outcomes, and advantages and challenges

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ABSTRACT

Mobile learning (m-learning) is a crucial educational technology for teacher education due to its significant benefits and the development of mobile technology. This study's objective is to conduct a systematic review and present a recent synthesis of the m-learning literature from 2018 to 2023 in teacher education relating to subject publication year, geographic distribution, matter domains, mobile devices and technologies used, research methodologies used to examine the implementation of m-learning, results for pre-service teachers, as well as benefits and challenges of m-learning adoption. The study used the systematic review methodology and PRISMA guidelines. A list of 27 studies was included from several relevant studies in four, Google Scholar, Mendeley, ScienceDirect, and Scopus, databases using inclusion and exclusion criteria to evaluate the full text after screening the titles and abstracts. The results of this study show that m-learning has garnered interest in numerous nations worldwide, applied in different subject matter domains with the use of various mobile devices and technologies. More significantly, the findings show that using mobile learning to learn positively impacts how pre-service teachers develop their knowledge, skills, and attitudes. Additionally, adopting this learning style recently in teacher education has certain advantages and challenges, requiring lecturers, pre-service teachers, and institutions to have the necessary equipment for knowledge, skills and facilities to achieve efficiency. Consequently, the results of this study can be used as a guide for research on m-learning in the future and contribute to the body of knowledge about this pedagogical strategy for teacher training.

Keywords: m-learning, pre-service teacher, systematic review, teacher education

INTRODUCTION

The growth of mobile technology in education has created various teaching and learning mediums, providing educators with new teaching approaches (Galway et al., 2020; Srisawasdi et al., 2018), including mobile learning (m-learning). This learning style in non-formal and elective educational settings presents opportunities to improve teaching and support innovation in schools and beyond (Hall & Connolly, 2019).

Brick-and-mortar classrooms become inaccessible to the stakeholders, especially as the COVID-19 pandemic spreads globally in early 2020; digital learning and m-learning with mobile devices offer a solution for this situation by removing barriers like limited time and space (Ata & Cevik, 2019; Islamoglu et al., 2021; Mulenga & Marbán, 2020).

M-learning is characterized as a method of instruction, where the technology used is entirely mobile, and the technology users are also mobile while learning (McQuiggan et al., 2015; as cited in Srisawasdi et al., 2018). M-learning in this context refers to the use of mobile devices for both teaching and learning (Ata & Cevik, 2019; Kearney & Maher, 2019), which are small, portable gadgets that can be used for computing, information storage and retrieval, as well as multimedia and communication (Kalogiannakis & Papadakis, 2019). Particularly, portable media players, smartphones, tablets, personal digital assistants, and e-book readers are examples of mobile devices frequently used in m-learning (Gupta et al., 2021; Kärki et al., 2018; Kuo et al., 2023).

Regarding the characteristics of m-learning, Li et al. (2019) and Parmigiani et al. (2019), rather than focusing on enabling learners to learn through mobile technology, this learning style focuses on enabling them to learn through contexts, where there is a close relationship between the variables students, teachers, contents, learning environments, and assessment. M-learning allows students to use their gadgets, including smartphones and tablets (Kuo et al., 2023), and are completely independent of university-proprietary software and hardware (Handal et al., 2019), which encourages learning in students' personal physical and virtual environments outside of the classroom (Kärki et al., 2018). In light of this, m-learning prioritizes mobility, access, immediacy, situatedness, ubiquity, convenience, collaboration, and contextuality, and this method of instruction has mobility characteristics in physical, conceptual, and social spaces (Baran, 2014; Li et al., 2019).

With the features above, numerous studies have shown that m-learning enables educators and learners to engage in experiential and situated learning without being constrained by time, place, or technological constraints (Handal et al., 2019). This extends the traditional teacher-led classroom scenario through informal learning activities outside the classroom (Srisawasdi et al., 2018), improving self-directed learning. Additionally, the use of mobile devices and technologies in the classroom can foster a positive learning environment (Handal et al., 2019), allowing students to collaborate, seek information, and participate in the knowledge-formation process (Dwikoranto et al., 2020), and enhance student-teacher and learner-learner interaction and communication (Li et al., 2019). Furthermore, this method of instruction allows learners to apply knowledge and skills immediately (Srisawasdi et al., 2018) and can receive instant communication and feedback (Haggag, 2018; Papadakis, 2018), thus helping students achieve higher levels of knowledge (Parmigiani et al., 2019).

Along with its many benefits, m-learning also presents stakeholders with some difficulties. Numerous studies have shown that the readiness of educators and students to adopt new technology and learning styles is a necessary condition for m-learning to be effective (Kalogiannakis & Papadakis, 2019). The main variables influencing the application of m-learning in teacher instruction are educators' information and communication technology skills, experience using mobile devices, pedagogical knowledge, and skills (Srisawasdi et al., 2018). On the other hand, studies also suggest that learners' basic and advanced mobile device skills, learning motivations, beliefs, attitudes, perceptions, and values (Li et al., 2019) as well as their age, gender (Habibi et al., 2022), ability, experience, learning styles, culture, daily average internet usage time (Eroglu et al., 2017) and possession of devices, their price, and their nature (Oluwadara et al., 2020) all have some effect on how effective m-learning is.

M-learning has emerged as a potential method of instruction in higher education (Asghar et al., 2021). Studies by Goundar and Kumar (2022) and Sobral (2020) show an increase in the interest of researchers in adopting m-learning in higher education. The bibliometric study of Sobral (2020) that examines 450 relevant articles from Scopus and WoS indicates that the number of research publications increased every year from 2007-2019 and sharply surged from 2015 to 2019, with the affiliation of authors from 64 countries. Additionally, adopting mobile technologies by teachers is a successful strategy for changing conventional teaching methods into student-centered ones (Srisawasdi et al., 2018). As a result, in order to prepare them for the classroom, pre-service teachers must gain practical experience using mobile devices and applications.

Petko et al. (2019) claim that using mobile technologies to take notes in written text, photographs, audio recordings, or videos opens new avenues for promoting reflection in teacher education. Pre-service teachers can investigate and comprehend the benefits and drawbacks of m-learning as they use mobile technology to learn, which will help them utilize this method of learning more effectively in their future teaching practices (Allen & Hadjistassou, 2018; Hall & Connolly, 2019; Li et al., 2021).

Different teacher education programs have made it possible for pre-service teachers to access m-learning practices in both forms: teacher training about and with m-learning (Baran, 2014; Islamoglu et al., 2021). This is to meet the need to improve pre-service teachers' digital competencies and enable them to function effectively in the digital learning environments of m-learning. According to Kearney and Maher (2019), teacher education with this learning strategy focuses on enhancing professional learning with mobile devices instead of teacher education about this learning strategy, which teaches pre-service teachers how to incorporate mobile devices into their teaching practices.

Numerous thorough reviews have examined various facets of m-learning's use in higher education. A study by Gupta et al. (2021) synthesizes earlier research on mobile learning tools and platforms that support synchronous and asynchronous teaching and learning techniques for college students and faculty. According to Tlili et al. (2022), however, little focus has been placed on pedagogy in mobile learning. As a result, a systematic review of 165 empirical studies on this learning approach was conducted to examine the evolving m-learning pedagogy landscape. Crompton and Burke (2018) also systematically analyzed m-learning studies conducted in higher education settings from 2010 to 2016 to examine the objectives, results, methodologies, domains of the studied subjects, educational levels, contexts of the studies, types of devices, and geographic distribution. Researchers and educators are becoming more interested in integrating mobile technologies into contexts for pre-service and in-service teachers (Gao et al., 2021). However, few studies on this learning style in teacher education have examined the advantages and insights into pre-service teachers' learning (Baran, 2014). As a result, to fill this gap, this systematic study was carried out to investigate various aspects of this learning approach in teacher education through an analysis of studies carried out in the years 2018–2023. The factors considered in this analysis included publication year, geographical distribution, subject matter domains, types of mobile devices used, research methodologies, pre-service teacher outcomes, and advantages and challenges of adopting m-learning in teacher education.

Goals & Research Questions for the Study

This study aims to offer a thorough and up-to-date review of the adoption of m-learning in teacher education from 2018 to March 2023. This review's specific objectives are outlined in the following research questions.

Research question 1. What are the demographics of the selected articles, such as the year of publication, geographical distribution, subject matter domains, mobile device types, and technological supports?

Research question 2. Which methodologies are utilized in the studies of m-learning in teacher education?

Research question 3. What are the primary outcomes of m-learning in teacher education for pre-service teachers?

Research question 4. What are m-learning's advantages and challenges when applied to teacher education?

METHOD

Design

PRISMA guidelines are used in a systematic review to address the research above questions (Moher et al., 2010). Primary research studies are chosen, identified, and synthesized to give a complete and trustworthy representation of the topic under review (Oakley, 2012). A systematic review is described by Dempster (2011; cited in Hanley & Cutts, 2013) as a comprehensive review of the literature, which is different from a traditional literature review in that it is carried out methodically (or systematically) according to a pre-established protocol to reduce bias and synthesize the information retrieved. The studies by Andersen et al. (2022), Crompton and Burke (2018), and Gupta et al. (2021) also used the study above design and the application of

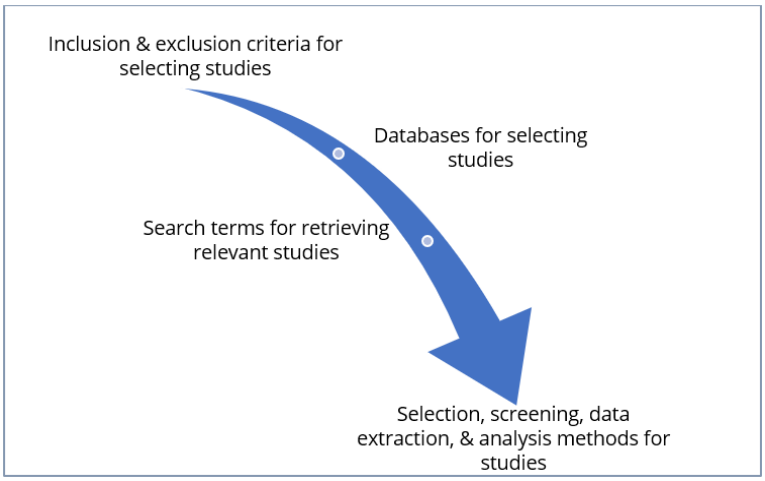

Figure 1. Protocols for study selection (Source: Authors)

PRISMA guidelines. In order to address the research questions, it is intended to investigate particular articles. A search protocol was established after the review's research questions were completed. This protocol was necessary to lessen the possibility of research bias (Kitchenham & Charters, 2007; cited in Alammary, 2019). The protocols are shown in **Figure 1**.

Search Limits

The search was limited to peer-reviewed English articles released between 2018 and March 2023. If different articles by the same researchers met the search criteria, they could also be included.

Inclusion Criteria & Exclusion Criteria

The studies chosen to use various research techniques, either experimental or survey. The use of mobile learning in teacher education, the context of teacher education, and a description of an experiment or survey on the use, advantages, and disadvantages of m-learning in teacher education were the three requirements an article had to meet to be considered for inclusion.

Articles were disqualified if they met any of the following criteria:

(a) neither an experiment nor a survey made up the research design,

(b) the instructional strategy was not m-learning,

(c) the findings did not address the application, advantages, and difficulties of m-learning in teacher education, or

(d) Not teacher education was the context.

Search Methods

Many online databases, including Google Scholar, Mendeley, ScienceDirect, and Scopus were chosen to search for relevant studies on the utilization of m-learning in teacher education due to their online accessibility and the wide variety of education-related research they provide. In order to choose studies that were included in the Scopus index, a search through the Scopus resource system was done as part of this study.

According to the requirements of the particular database, relevant studies were sought using the Boolean search filtering and the following search strings with variously adjusted syntaxes, including (mobile learning) AND (teacher education), (mobile learning) AND (pre-service teachers), (mobile learning) AND (pre-service teacher), (m-learning) AND (teacher education), (m-learning) AND (pre-service teachers), (m- learning) AND (pre-service teacher).

In contrast, the authors independently searched databases for studies based on search terms and included and excluded studies through screenings of full texts compared with inclusion and exclusion criteria to avoid bias in study selection. The remaining reviewers will be contacted if there is a disagreement or

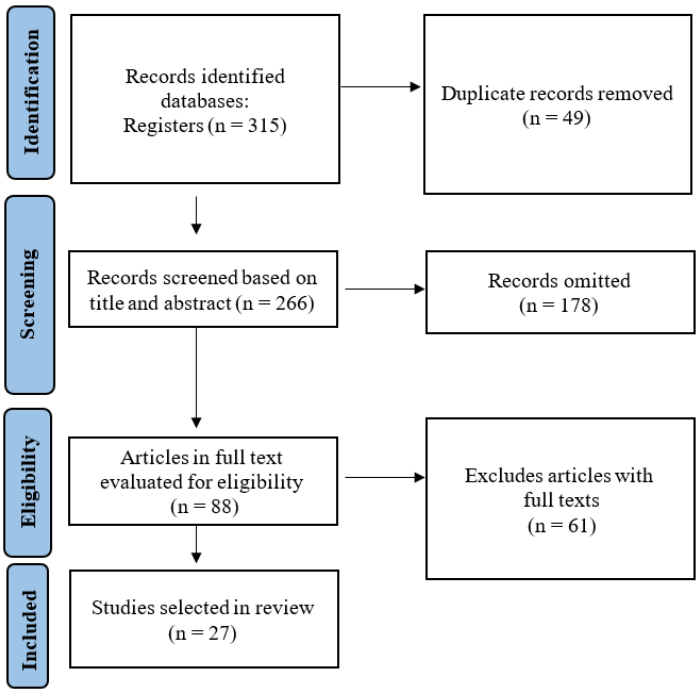

Figure 2. PRISMA process flowchart based on Moher et al. (2010)

ambiguity during the screening process. The authors then appraise the methodological quality of the included articles. Criteria for methodological research include the quality of all important aspects, including theoretical background, study design, data collection, data analysis, interpretation, and conclusions. Two critical appraisers will rigorously evaluate each paper chosen for this systematic review before it is included. The selected studies are those with consensus from all authors after discussion.

Data Extraction & Analysis

End-Note reference management program will compile a database of these studies, including their titles, abstracts, and full texts. The data to be extracted from the selected studies include

(a) demographic details of the selected articles (the year of publication, geographic distribution, subject matter domains, types of mobile devices and technological supports),

(b) research methods (research design, sample, assessment instruments), and

(c) main findings (primary outcomes, advantages and challenges of m-learning).

Discussion will be used to settle disagreements between authors after data extraction.

Based on the demographic information, research methods, and key findings from the selected studies, a results report for the data synthesis will be created, highlighting the themes that arose from the research questions. Firstly, demographic details will be examined. The distribution of publication years and the authors' affiliated nations will be provided, and the data will be set up in tables or shown graphically. Second, the research design, sample, and instruments used in the selected studies' methodology will be examined. The findings from the selected research will next be compiled to highlight the benefits and difficulties of adopting m-learning in teacher education.

Search Outcomes

315 articles regarding the search terms were found. End-Note reference management program compiled these articles' titles, abstracts, and full texts in a database. After removing duplicates and carefully examining article titles and abstracts, there were only 88 articles left. The articles that should be included were chosen after a full-text evaluation and eligibility analysis. 61 articles were removed from consideration because they did not fit the criteria. For this systematic review's investigation, the process kept 27 pertinent articles. Specifically, **Figure 2** explains how articles are chosen following PRISMA's recommendations.

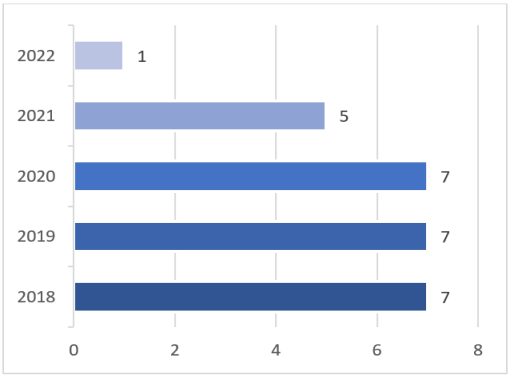

Figure 3. Distribution of selected studies' publication years (Source: Authors)

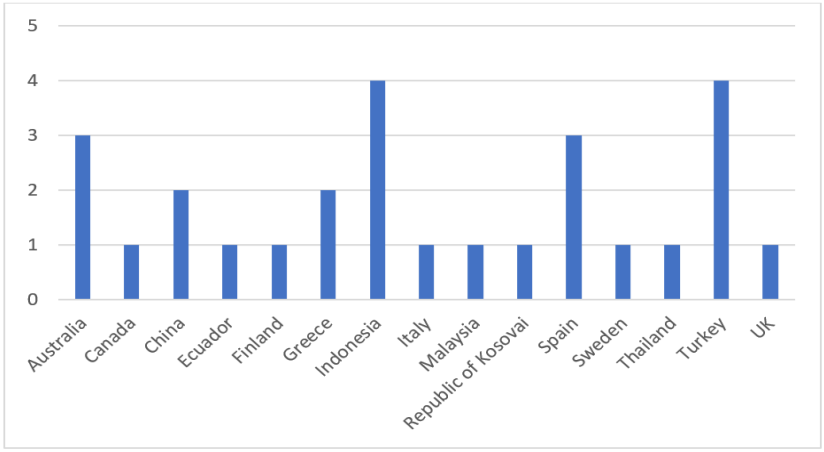

Figure 4. Included articles' geographic distribution (Source: Authors)

RESULTS

Demographic Details

Research question 1. What are the demographics of the selected articles, such as the year of publication, geographical distribution, subject matter domains, mobile device types, and technological supports?

Year of publication

Figure 3 displays the breakdown of the included studies' publication years. The number of studies published in 2018, 2019, and 2020 accounts for the highest proportion of the 27 included studies, with seven published each year (accounting for 26%). Additionally, there are five studies published in 2021 (accounting for 18%) and 1 study published in 2022 (accounting for 4%), and as of March 2023, no studies match the scope of this study. Many more studies were conducted in the years 2019-2020 than in the years 2021-2023. Numerous countries are experiencing a severe COVID-19 epidemic, disrupting in-person instruction. For this reason, m-learning can be considered a quick and efficient solution to address the need for distance learning in higher education, the condition that most students own smart mobile devices (Asghar et al., 2021).

Geographic distribution

The locations of the included studies are represented by the affiliation countries of the authors in **Figure 4**. Among 27 included studies, Indonesia and Turkey had the highest number of studies (four), and Australia and Spain (three). Other studies were performed in China=2, Greece= 2, Canada=1, Ecuador=1, Finland=1, Italy=1, Malaysia=1, Republic of Kosovo=1, Sweden=1, Thailand=1, and UK=1. According to a study by Al-Adwan et al. (2018), while m-learning has gained widespread adoption in developed nations, it is still in its infancy and underdevelopment there. Nevertheless, findings in **Figure 4** demonstrate that many developing nations have recently shown much interest in implementing this learning strategy in teacher training.

Table 1. Domains of included articles' subject matter

No	Subjects	Included articles	n	P (%)
1	Chemistry	Li et al. (2019)	1	3.70
2	ELF	Allen and Hadjistassou (2018), Annamalai (2018), Cabrera-Solano et al. (2019), Haerazi et al. (2020), Kearney and Maher (2019), Li et al. (2021), Nariyati et al. (2020), & Pratiwi et al. (2020)	8	29.63
3	English	Naylor and Gibbs (2018)	1	3.70
4	Didactic program	Soler Costa et al. (2020)	1	3.70
5	Information technology	Islamoglu et al. (2021)	1	3.70
6	Mathematics	Handal et al. (2019), & Kearney and Maher (2019)	2	7.41
7	Preschool education	Kalogiannakis and Papadakis (2019)	1	3.70
8	Primary education	Gómez-García et al. (2021)	1	3.70
9	Science	Inel-Ekici and Ekici (2022), Kearney and Maher (2019), Naylor and Gibbs (2018), & Srisawasdi et al. (2018)	4	14.81
10	Not mentioned	Aman et al. (2020), Asghar et al. (2021), Ata and Cevik (2019), Galway et al. (2020), Kärki et al. (2018), Papadakis (2018), Parmigiani et al. (2019), Qarkaxhja et al. (2021), Townsend (2018), & Uzunboylu et al. (2020)	10	37.04

Note. n: Number of articles & P: Percentage

Table 2. Mobile device types employed in included studies

No	Mobile device types	Included articles	n	P (%)
1	Smartphones	Cabrera-Solano et al. (2019), Handal et al. (2019), Kalogiannakis and Papadakis (2019), Kearney and Maher (2019), & Parmigiani et al. (2019)	5	18.52
2	Tablets/iPads	Allen and Hadjistassou (2018), Galway et al. (2020), Handal et al. (2019), Kalogiannakis and Papadakis (2019), Kearney and Maher (2019), & Naylor and Gibbs (2018)	6	22.22

Note. n: Number of articles & P: Percentage

Subject matter domains

As shown in **Table 1**, m-learning can be used to teach various subjects in teacher education. English as a foreign language (EFL) and science are the two subject matter domains that account for the highest percentage of 27 included studies, with 29.63% and 14.81%, respectively. There are many different communication modalities involved in language learning. By providing tools that make language learning more accessible and commonplace, mobile devices can support these modalities in several different ways (Crumpton & Burke, 2018). Besides, m-learning is also applied in teaching areas such as mathematics (2 studies, accounting for 7.41%), chemistry, English, didactic program, information technology, primary education and preschool education (one study, accounting for 3.70%).

Mobile device types

Table 2 shows that eight out of the 27 studies on m-learning in teacher training specifically identify the kind of mobile devices they used, while the remaining studies only refer to the utilization of various mobile technologies in general. In particular, smartphone use in m-learning is emphasized in five studies by Cabrera-Solano et al. (2019, Handal et al. (2019), Kalogiannakis and Papadakis (2019), Kearney and Maher (2019), and Parmigiani et al. (2019). Meanwhile, six studies by Allen and Hadjistassou (2018), Galway et al. (2020), Handal et al. (2019), Kalogiannakis and Papadakis (2019), Kearney and Maher (2019), and Naylor and Gibbs (2018) use tablets (or iPads) as the primary learning tool in computer science. The two types of mobile devices most frequently employed in m-learning research at universities are smartphones and tablets (or iPads). These two mobile devices are easily accessible and have a high ownership rate in higher education, which may account for the above conclusion (Annamalai, 2018).

Technological supports

Various types of technological supports have been utilized in the application of m-learning. Of the 27 included studies, 14 specifically mention technological tools used, some of which use more than two types of technological tools. The tools used to communicate and exchange educational materials and to carry out learning activities comprise the two main categories of technological support mentioned in the studies. The group of tools used to communicate and exchange learning materials reported in included studies includes

Table 3. Included articles' research design types

No	Research design types	Included articles	n	P (%)
1	Survey	Aman et al. (2020), Asghar et al. (2021), Ata and Cevik (2019), Islamoglu et al. (2021), Kalogiannakis and Papadakis (2019), Kärki et al. (2018), Li et al. (2021), Nariyati et al. (2020), Naylor and Gibbs, (2018), Papadakis (2018), Parmigiani et al. (2019), Qarkaxhja et al. (2021), & Townsend (2018)	13	48.15
2	Experimental study	Cabrera-Solano et al. (2019), Gómez-García et al. (2021), Haerazi et al. (2020), Inel-Ekici and Ekici (2022), Islamoglu et al. (2021), Li et al. (2019), Parmigiani et al. (2019), Soler Costa et al. (2020), & Srisawasdi et al. (2018)	9	33.33
3	Interview	Aman et al. (2020), Ata and Cevik (2019), & Townsend (2018)	3	11.11
4	Case study	Annamalai (2018) & Kearney and Maher (2019)	2	7.41
5	Report study	Allen and Hadjistassou (2018) & Galway et al. (2020)	2	7.41
6	Mixed methods	Ata and Cevik (2019) & Pratiwi et al. (2020)	2	7.41

Note. n: Number of articles & P: Percentage

Table 4. Included articles' research method types

No	Research method types	Included articles	n	P (%)
1	Qualitative	Allen and Hadjistassou (2018), Annamalai (2018), Inel-Ekici and Ekici (2022), Galway et al. (2020), Kearney and Maher (2019), Qarkaxhja et al. (2021), Srisawasdi et al. (2018), Townsend (2018), & Uzunboylu et al. (2020)	9	33.33
2	Quantitative	Asghar et al. (2021), Gómez-García et al. (2021), Islamoglu et al. (2021), Kalogiannakis and Papadakis 2019), Kärki et al. (2018), Li et al. (2021), Papadakis (2018), & Soler Costa et al. (2020)	8	29.63
3	Mixed methods	Aman et al. (2020), Ata and Cevik (2019), Cabrera-Solano et al. (2019), Haerazi et al. (2020), Handal et al. (2019), Li et al. (2019), Nariyati et al. (2020), Naylor and Gibbs (2018), Parmigiani et al. (2019), & Pratiwi et al. (2020)	10	37.04

Note. n: Number of articles & P: Percentage

Edutopia, Edmodo (Kearney & Maher, 2019), Email (Haerazi et al., 2020), Facebook (Kearney & Maher, 2019), Google Classroom (Islamoglu et al., 2021), Google Drive (Parmigiani et al., 2019), LinkedIn (Kearney & Maher, 2019), Pinterest (Kearney & Maher, 2019), Twitter (Kearney & Maher, 2019), Youtube (Kearney & Maher, 2019), WhatsApp (Annamalai, 2018; Haerazi et al., 2020; Soler Costa et al., 2020). The set of tools used to perform learning tasks and activities include ActionTrack (Kärki et al., 2018), Kahoot (Uzunboylu et al., 2020), mobile-assisted language learning MALL (Li et al., 2021; Nariyati et al., 2020; Pratiwi et al., 2020), Moodle (Allen & Hadjistassou, 2018; Soler Costa et al., 2020), mobile laboratory learning in science (Srisawasdi et al., 2018), U-dictionary (Haerazi et al., 2020), visual vocabulary app (Cabrera-Solano et al., 2019), AR technology (Gómez-García et al., 2021). In particular, most of the above tools are easily accessible on mobile devices and are provided free of charge. This makes it easier to apply m-learning to teacher education (Cabrera-Solano et al., 2019; Uzunboylu et al., 2020).

Methodologies Utilized in the Included Studies

Research question 2. Which methodologies are utilized in the studies of m-learning in teacher education?

Research designs

As seen in **Table 3**, numerous studies investigating various facets of m-learning implementation in teacher education have been carried out using various research designs, some of which use multiple simultaneous applications of different research designs. The data speculates that survey and experimental research design are the two types of research designs with the highest percentage, with 13 studies (accounting for 48.15%) and nine studies (accounting for 33.33%). The remaining studies reported using interview research design (three studies), case study (two studies), report study (two studies), and mixed methods design (two studies).

According to **Table 4**, among the 27 included studies, there is a relatively even distribution of research methods used. Specifically, ten studies are using mixed methods (accounting for 37.04%), nine qualitative studies (accounting for 33.33%) and eight quantitative studies (accounting for 29.63%). Thus, it can be seen that researchers use a variety of ways of investigating the implementation of m-learning, providing suggestions on research design directions for future studies.

Table 5. Instrument types utilized in chosen articles

No	Instrument types	Chosen articles	n	P (%)
1	Questionnaires	Aman et al. (2020), Asghar et al. (2021), Ata and Cevik (2019), Cabrera-Solano et al. (2019), Handal et al. (2019), Kalogiannakis and Papadakis (2019), Kärki et al. (2018), Li et al. (2019), Li et al. (2021), Nariyati et al. (2020), Papadakis (2018), Parmigiani et al. (2019), Pratiwi et al. (2020), Qarkaxhja et al. (2021), Srisawasdi et al. (2018), & Townsend (2018)	16	59.26
2	Interviews	Aman et al. (2020), Annamalai (2018), Ata and Cevik (2019), Cabrera-Solano et al. (2019), Inel-Ekici and Ekici (2022), Li et al. (2019), Nariyati et al. (2020), Naylor and Gibbs (2018), Pratiwi et al. (2020, Naylor and Gibbs (2018), Townsend (2018), & Uzunboylu et al. (2020)	12	44.44
3	Tests	Cabrera-Solano et al. (2019), Gómez-García et al. (2021), Haerazi et al. (2020), Parmigiani et al. (2019), & Srisawasdi et al. (2018)	5	18.52
4	Observations	Haerazi et al. (2020) & Li et al. (2019)	2	7.41
5	Artifacts	Allen and Hadjistassou (2018) & Kearney and Maher (2019)	2	7.41
6	Participant journals	Kearney and Maher (2019)	1	3.70

Note. n: Number of articles & P: Percentage

Sample

The included studies report on pre-service teachers from various disciplines in teacher education. These studies have quite a large difference in sample size in which the study with the largest sample size is 429 participants, and the smallest is six. There are 13 studies conducted with a sample size larger than 100 (Aman et al. al., 2020; Asghar et al., 2021; Ata & Cevik, 2019; Gómez-García et al., 2021; Handal et al., 2019; Islamoglu et al., 2021; Kärki et al., 2018; Li et al., al., 2019; Li et al., 2021; Papadakis, 2018; Soler Costa et al., 2020; Srisawasdi et al., 2018; Townsend, 2018), respectively, seven studies were performed with sample sizes from 50 to less than 100 participants (Haerazi et al., 2020; Inel-Ekici & Ekici, 2022; Kalogiannakis & Papadakis 2019; Nariyati et al., 2020; Parmigiani et al., 2019; Pratiwi et al., 2020; Qarkaxhja et al., 2021) and less than 50 participants (Allen & Hadjistassou, 2018; Annamalai, 2018; Cabrera-Solano et al., 2019; Galway et al., 2020; Kearney & Maher, 2019; Naylor & Gibbs, 2018; Uzunboylu et al., 2020). Research designs like surveys and interviews are typically used in studies with large sample sizes. Experimental studies often have medium sample sizes (from 50 to 100) or small (less than 50), while case studies and report studies often have relatively small sample sizes (less than 50).

Instruments

Table 5 indicates that diverse instruments were employed in the studies included in the compilation to look into various facets of m-learning's application to teacher education. Many studies have used more than one instrument for different research purposes. 59.26% of the studies used questionnaires (16 studies), and 44.44% used interviews (12 studies), the two most commonly used tools. Additionally, tests (five studies, accounting for 18.52%), observations (two studies, accounting for 7.41%), artifacts (two studies, accounting for 7.41%) and participant journals (one study, accounting for 3.70%). As can be seen, questionnaires, interviews and tests are commonly used in included studies. In particular, studies using questionnaires and interviews often have relatively large sample sizes, which increases the reliability and representativeness of the population of the collected results (Anokye, 2020).

Pre-service Teacher Outcomes of M-Learning

Research question 3. What are the primary outcomes of m-learning in teacher education for pre-service teachers?

Table 6 lists student outcomes mentioned in the 27 selected studies for knowledge, skills, and attitude. In terms of knowledge, studies have reported improvement of pre-service teachers in pedagogical knowledge (one study), technological knowledge (two studies), technological pedagogical knowledge (two studies), technological content knowledge (two studies) and academic performance (four studies). Thus, it can be proven that enhancing teachers' technology pedagogical and content knowledge (TPACK) in m-learning becomes effective.

Table 6. Outcomes of m-learning for pre-service teachers

No	PST outcomes	Selected articles	n	P (%)
Knowledge				
1	Pedagogical knowledge	Li et al. (2021)	1	3.70
2	Technological knowledge	Li et al. (2021) & Srisawasdi et al. (2018)	2	7.41
3	Technological pedagogical knowledge	Nariyati et al. (2020) & Srisawasdi et al. (2018)	2	7.41
4	Technological content knowledge	Nariyati et al. (2020) & Srisawasdi et al. (2018)	2	7.41
5	Academic performance	Cabrera-Solano et al. (2019), Haerazi et al. (2020), Parmigiani et al. (2019), & Qarkaxhja et al. (2021)	4	14.81
Skills				
6	Higher cognitive level thinking	Galway et al. (2020) & Inel-Ekici and Ekici (2022)	2	7.41
7	Critical thinking	Haerazi et al. (2020), Kärki et al. (2018), & Parmigiani et al. (2019)	3	11.11
8	Problem-solving skills	Inel-Ekici and Ekici (2022), Kärki et al. (2018), & Soler Costa et al. (2020)	3	11.11
9	Reflective thinking	Parmigiani et al. (2019)	1	3.70
10	Pedagogical skills	Li et al. (2021)	1	3.70
11	Technology integration skills	Kalogiannakis and Papadakis (2019) & Li et al. (2021)	2	7.41
12	Research skills	Inel-Ekici and Ekici (2022) & Qarkaxhja et al. (2021)	2	7.41
13	Social interaction/communication	Aman et al. (2020), Asghar et al. (2021), Galway et al. (2020), Parmigiani et al. (2019), Soler Costa et al. (2020), Townsend (2018), & Uzunboylu et al. (2020)	7	25.93
14	Cooperation/Collaboration	Asghar et al. (2021), Cabrera-Solano et al. (2019), Galway et al. (2020), Handal et al. (2019), Kärki et al. (2018), Kearney and Maher (2019), Nariyati et al. (2020), & Townsend (2018)	8	29.63
15	Independence learning	Cabrera-Solano et al. (2019), Handal et al. (2019), Kearney and Maher (2019), & Nariyati et al. (2020)	4	14.81
16	Autonomy in learning	Soler Costa et al. (2020)	1	7.41
17	Deep learning	Nariyati et al. (2020)	1	11.11
Attitude				
18	Positive learning attitude	Cabrera-Solano et al. (2019), Papadakis (2018)	2	7.41
19	Active engagement	Aman et al. (2020), Annamalai (2018), Galway et al. (2020), Kärki et al. (2018), & Li et al. (2019)	5	18.52
20	Motivation	Cabrera-Solano et al. (2019), Gómez-García et al. (2021), Soler Costa et al. (2020), & Uzunboylu et al. (2020)	4	14.81
21	Self-confidence	Cabrera-Solano et al. (2019) & Islamoglu et al. (2021)	2	7.41
22	Self-directed learning awareness	Annamalai (2018)	1	3.70
23	Self-efficacy awareness	Islamoglu et al. (2021) & Parmigiani et al. (2019)	2	7.41
24	Awareness of technology integration	Cabrera-Solano et al. (2019) & Pratiwi et al. (2020)	2	7.41
Others				
25	Meaningful learning experiences	Aman et al. (2020) & Asghar et al. (2021)	1	3.70
26	Time-saving	Ata and Cevik (2019)	1	3.70

Note. PST: Pre-service teacher; n: Number of articles & P: Percentage

Furthermore, studies on skill development indicate that the improvement of cognitive, professional, and soft skills is facilitated by m-learning. Two studies document the effectiveness of this learning style for higher cognitive level thinking in general, and specifically critical thinking (three studies), problem-solving skills (three studies), and reflective thinking (one study). In contrast, the application of m-learning in instructing teacher education subjects also contributes to the growth of future teachers' pedagogical skills (one study), technology integration skills (two studies) and research skills (two studies). Furthermore, through interactive activities, communication through social networking platforms and online classes of lecturer-students and students-students, as well as through group work, m-learning is reported to positively impact the development of communication skills (seven studies) and cooperation (eight studies) of pre-service teachers. Besides, due to the organizational features of this learning strategy, pre-service teachers can practice effective study skills, such as independent learning (four studies), autonomy in learning (one study), and deep learning (one study), in a supportive online learning environment with activities that encourage self-study.

Table 7. Advantages of m-learning adoption in teacher education

No	Advantages	Selected articles
1	Easy utilization of mobile devices	Aman et al. (2020), Annamalai (2018), Cabrera-Solano et al. (2019), Papadakis (2018), & Uzunboylu et al. (2020)
2	Easy Internet accessibility	Annamalai (2018), Qarkaxhja et al. (2021)
3	Free cost & immediate availability of technological applications	Cabrera-Solano et al. (2019), Parmigiani et al. (2019), & Uzunboylu et al. (2020)
4	High ownership rates of mobile devices	Annamalai (2018), Papadakis (2018), & Parmigiani et al. (2019)
5	Free cost of Internet services at universities	Annamalai (2018)
6	Flexibility in times & places of learning	Annamalai (2018), Asghar et al. (2021), Parmigiani et al. (2019), & Townsend (2018)
7	M-learning readiness & perceptions among pre-service teachers	Annamalai (2018), Papadakis (2018), & Pratiwi et al. (2020)

In terms of learning toxicity, m-learning stimulates pre-service teachers' positive learning attitude (two studies), active learning engagement (five studies), and learning motivation (four studies). Also, through independent learning and communication activities, pre-service teachers also improve their self-confidence (two studies), self-directed learning awareness (one study), and self-efficacy awareness (one study). Additionally, pre-service teachers develop an awareness of technology integration in their future teaching through the combined utilization of various technologies in learning and through observation of the organization of lectures with technological support.

Furthermore, applying m-learning in teaching with diverse learning activities and a flexible learning environment also brings learners meaningful learning experiences (one study) and, at the same time, contributes to saving time for both lecturers and pre-service teachers (one study) because delivering learning materials, communicating, discussing and performing tasks can all be done outside the classroom through the aid of technology.

Advantages & Challenges of Adopting M-Learning in Teacher Education

Research question 4. What are m-learning's advantages and challenges when applied to teacher education?

Advantages

According to **Table 7**, the rapid advancement of technology and improved teaching methods at universities have created numerous favorable conditions for lecturers and students to use this instructional approach to teaching and study. In terms of technology, included studies reported that the easy utilization of mobile devices (five studies), the easy accessibility of the Internet (two studies), the free cost and immediate availability of technological applications (three studies), the high ownership rates of mobile devices (three studies) facilitate the m-learning adoption. Smartphones and tablets, in particular, are frequently used mobile devices, and the technological tools used in the included studies were frequently made available without charge. Additionally, the university learning environment provides free Internet access (one study), the learning program allows for flexibility in learning times and locations (four studies), and pre-service teachers' perceptions and readiness for m-learning (three studies), are all significant factors supporting the widespread use of m-learning in teacher education. Pre-service teachers' perceptions and readiness are critical for determining their attitudes and levels of engagement in their learning, which directly impacts how well this learning style works.

Challenges

Table 8 shows numerous challenges lecturers, pre-service teachers, and universities must overcome to implement m-learning in the classroom successfully. The first is the challenges posed to lecturers. The included studies reported that lecturers' digital competency (two studies), instructor support (one study), classroom management (one study), general pedagogical shift (one study) and the availability of m-learning teaching resources (one study) are the challenges that lecturers need to overcome. The second is the difficulties of pre-service teachers, including their digital competency (three studies), personal innovation (two

Table 8. Challenges of m-learning adoption in teacher education

No	Challenges	Selected articles
1	Lecturer's digital competency	Annamalai (2018) & Qarkaxhja et al. (2021)
2	Instructor support	Galway et al. (2020)
3	Classroom management	Handal et al. (2019)
4	General pedagogical shift	Galway et al. (2020)
5	Availability of m-learning teaching resources	Handal et al. (2019)
6	Pre-service teachers' digital competency	Annamalai (2018), Kearney and Maher (2019), & Qarkaxhja et al. (2021)
7	Personal innovation	Asghar et al. (2021) & Ata and Cevik (2019)
8	Pre-service teachers' self-directed learning & self-efficacy	Ata and Cevik (2019) & Qarkaxhja et al. (2021)
9	Pre-service teachers' discipline & organization	Allen and Hadjistassou (2018), Li et al. (2019), & Qarkaxhja et al. (2021)
10	Pre-service teachers' readiness	Handal et al. (2019) & Li et al. (2019)
11	Communicative overload	Parmigiani et al. (2019)
12	Social influence	Asghar et al. (2021)
13	Requirement of time & energy	Galway et al. (2020) & Parmigiani et al. (2019)
14	Equity in student access	Galway et al. (2020)
15	Cross-platform compatibility	Galway et al. (2020), Kearney and Maher (2019), & Parmigiani et al. (2019)
16	Technical devices	Asghar et al. (2021), Ata and Cevik (2019), Galway et al. (2020), Handal et al. (2019), Parmigiani et al. (2019), Qarkaxhja et al. (2021), & Townsend (2018)
17	Network connectivity	Galway et al. (2020), Handal et al. (2019), Qarkaxhja et al. (2021), Townsend (2018), & Uzunboylu et al. (2020)
18	Quality of services	Asghar et al. (2021)
19	Technical issues	Qarkaxhja et al. (2021)

studies), their self-directed learning and self-efficacy (two studies), their discipline and organization (three studies), and their readiness (two studies). Additionally, this instructional approach also poses for both lecturers and pre-service teachers the issues of communicative overload (one study), social influence (one study), the requirement of time and energy (two studies), equity in student access (one study), cross-platform compatibility (three studies), technical devices (seven studies), network connectivity (five studies), quality of services (one study), technical issues (one study). In particular, the issues of infrastructure and technology also need to be considered by universities (Hall1 & Connolly, 2019).

DISCUSSION

This PRISMA-based systematic review was conducted to answer research questions about studies on using m-learning in teacher education from 2018 to 2023, including

(a) demographic details of the selected studies, including publication year, geographic distribution, subject matter domains, mobile device types and technology,

(b) research methodologies used in the included studies to examine the implementation of m-learning,

(c) pre-service teacher outcomes of m-learning, and

(d) advantages and challenges of the m-learning adoption in teacher education.

The first research question examines 27 included studies' demographic information, including publication year, geographic distribution, subject matter domains, mobile device types, and technology. Regarding publication year, the analysis results observed that the number of studies conducted in the two years 2019-2020 accounts for the highest proportion; this is also the period when the COVID-19 pandemic broke out in countries and learning needs of online, learning is on the rise (Dwikoranto et al., 2020; Roy & Covelli, 2020). Regarding geographic distribution, included studies were carried out in many countries on most continents, including developed and developing countries; this conclusion aligns with the findings of Crompton and Burke (2018). With the rapid growth of mobile technologies and the high ownership rate of smart mobile devices in other countries (Asghar et al., 2021), developing countries have the conditions to apply this learning style and are increasingly interested in this teaching approach. Regarding subject matter domains, m-learning is implemented in teaching pre-service teachers in many subjects in which EFL accounts for the highest

percentage. The author argues that learning a language involves many different communication modalities and that mobile devices can be used in various ways to support these modalities by providing tools that make language learning more widely available and accessible. Research by Crompton and Burke (2018) and Haggag (2018) also yields similar results. Besides, lecturers and pre-service teachers have used various mobile devices and technologies to organize teaching with m-learning. The most commonly used mobile devices specifically mentioned in a total of 27 included studies are smartphones and iPads (or tablets). These two mobile devices are easily accessible and have a high ownership rate in higher education, which may account for the above conclusion (Annamalai, 2018; Parmigiani et al., 2019). Also, mobile technologies reported in the included studies can be divided into two groups, including tools used to communicate and exchange learning materials such as social networking platforms, email and sharing platforms and document storage, and a group of tools used to perform learning activities such as learning software and electronic dictionaries. In particular, most of the above tools are easily accessible on mobile devices and are provided free of charge, creating favorable conditions for m-learning adoption in teacher education (Cabrera-Solano et al., 2019; Uzunboylu et al., 2020).

The second research question examines the methodologies used in 27 included studies to examine different aspects of m-learning in teacher education. The analysis results reveal that many studies have been conducted with different research designs to investigate different aspects of applying this learning strategy in teacher education. Survey and experimental research design are two types of research designs that accounted for the highest percentage. Also, by comparing the sample sizes of the studies, it can be seen that most of the studies with large sample sizes are studies with research designs, such as surveys and interviews, while experimental research, case studies, and reports. Studies usually have medium sample sizes (50 to 100) or small (less than 50). In addition, various instruments were used for different research purposes in the included studies, including questionnaires, interviews, tests, observations, artifacts, and participant journals. Questionnaires, interviews, and tests are commonly used tools in included studies and often have relatively large sample sizes, which increases the reliability and representativeness of the population of the collected results (Anokye, 2020). The results of research methodologies can be considered suggestions when designing research for new future m-learning studies.

The included studies provided information on the third research question, which looked at pre-service teachers' outcomes after using m-learning. The survey indicates that this learning strategy positively impacts pre-service teachers' knowledge acquisition, abilities, and attitudes. This result aligns with what Crompton and Burke (2018) discovered in their systematic review. The development of TPACK in pre-service teachers is specifically aided by this instructional strategy. In order to prepare literate pre-service teachers for using mobile technology in teaching practices, TPACK of m-learning for pre-service teachers has been recommended (Srisawasdi et al., 2018).

Additionally, the development of cognitive, professional, learning, and soft skills is positively impacted by mobile learning. In addition, this learning method gives students meaningful learning experiences and makes learning flexible regarding time and location, promoting pre-service teachers' positive learning participation and raising their awareness of technology integration. With these benefits, mobile learning has quickly become the preferred method for acquiring knowledge and integrating various learning styles (Gupta et al., 2021). However, to maximize the impact of m-learning programs, longer intervention times, more thorough assessment of higher-level skills, and closer curriculum and technology integration are all required (Papadakis, 2018).

The final research question examines the advantages and challenges of m-learning in teacher education. Numerous opportunities for m-learning have emerged due to the quick increase in mobile devices and the trend toward improving instructional techniques. Regarding technology, the easy accessibility of the Internet and technological applications and the high ownership rates of mobile devices, namely smartphones and tablets in universities, have facilitated lecturers and pre-service teachers to organize instruction with m-learning. Also, pre-service teachers' perceptions and readiness toward innovative teaching methods are important factors in promoting learning engagement with this learning approach. On the other hand, to effectively adopt m-learning, lecturers, pre-service teachers, and institutions face various difficulties. For lecturers, these challenges include their digital competency, classroom management, pedagogical shift abilities, and the availability of m-learning teaching resources. These difficulties for lecturers include their level of digital proficiency, ability to manage the classroom, capacity for pedagogical shift, and accessibility of m-

learning teaching materials. Besides, university educators and stakeholders should consider communicative overload, cross-platform compatibility, technical devices, network connectivity, and technical issues. These results could also help identify potential learning barriers before implementing mobile technologies in teacher education in future research (Islamoglu et al., 2021). In light of this, Gao et al. (2021) claim that efforts from lecturers and pre-service teachers, school management, learning resources, and network environment are required to increase the effectiveness of using m-learning. These include correcting learning attitudes and raising learning awareness, strengthening the construction of mobile network learning resources, strengthening network security management, and establishing a network environment.

In addition to these results obtained, this study has certain limitations. Firstly, the choice of databases may be restricted, resulting in fewer studies being included and a less diverse range of results. Thus, future systematic review studies may consider improving search strategies so that including relevant studies is guaranteed in quantity and quality. Secondly, the study analyzes the results of included studies in many aspects, but the issue of how to organize m-learning and the factors affecting lecturers' and prospective teachers' readiness to adopt m-learning has not been investigated within the scope of this study. The studies by Habibi et al. (2022), Kearney (2019), Papadakis (2018), and Tezer and Beyolu (2018) all addressed this issue. Accordingly, new studies could investigate the further analysis of these issues.

CONCLUSIONS

This systematic review using PRISMA guidelines has provided a recent synthesis of 27 m-learning studies from 2018 to 2023 in teacher education relating to publication year, geographical distribution, subject matter areas, mobile devices and technologies employed, research methodologies used to examine the implementation of m-learning, pre-service teacher outcomes, and advantages and challenges of adopting this learning style. The findings of this review reveal that this learning approach has been applied in various subjects with the utilization of different mobile devices and technologies in teacher education programs in many countries. According to the included studies, future teachers reportedly acquired professional knowledge, skills, and learning attitudes through m-learning. In addition, the growth of mobile technology and the trend of improving teaching methods create many opportunities for this learning strategy and pose certain challenges that lecturers, pre-service teachers and institutions need the necessary knowledge, skills and facilities.

The study's results can inform future m-learning research and provide stakeholders with insightful advice on this type of instruction. Lecturers can benefit from selecting mobile devices and technologies to improve their teaching design. At the same time, understanding the challenges that need to be overcome also helps lecturers and institutions better prepare knowledge, skills and facilities to improve the effectiveness of m-learning in teaching. In addition, researchers with research goals on this learning style can refer to the results of research methodologies to guide research design. Based on the study's findings and limitations, the following new research directions in m-learning are proposed for the future:

(a) carrying out a systematic review on the m-learning adoption in specific subjects of teacher education,

(b) conducting systematic review studies examining the impact of various factors on pre-service teachers' and lecturers' readiness to implement m-learning,

(c) expanding the use of article databases for systematic review, and

(d) enhanced measurement instruments and data analysis.

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