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Mobile learning in grades K–12: A literature review

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Highlights

- Mobile learning in K-12 grades from 2015 to 2021 is examined.
- The words mobile learning, learning anywhere, K-12 grades and systematic review are prominent.
- "Reporting the prerequisite tests of the analyzes used in the research", "validity and reliability studies", "reporting the effect size" and "the existence of ethical and legal permissions" criteria are also examined.

Article Info: Review Article

Keywords: *Mobile Learning, Systematic Review, Elementary Education, Secondary Education*

Abstract

Due to the widespread use of mobile technologies, their use of them in teaching processes has also increased. Within this framework, in this study, in-depth investigation of K-12 grades studies from 2015 to 2021 which were conducted on “mobile learning”, and “learning anywhere” published on “Web of Science” through specific criteria. A total of 4419 studies published only in English were accessed initially. Then, other keywords related to K-12 grades within the scope of the study were also searched, and 452 publications were reached. 336 studies that did not meet the inclusion criteria were excluded, and as a result, 109 studies were identified as primary studies. In this study, apart from the basic criteria used in previous literature review studies, criteria such as "reporting the prerequisite tests of the analyses used in the research", "validity, and reliability studies", "reporting the effect size", and "the existence of ethical, and legal permissions" are also included. The study could be considered important in terms of these additional criteria, and with its purpose of trying to reveal mobile learning tendencies.

1. Introduction

The e-learning approach has emerged, and developed rapidly as a result of the rapid change of technology, becoming a part of social life, and the interaction of the concepts of "technology, people, and education". Such developments have made it necessary to integrate technology into educational activities. The integration of technology into every aspect of life has also changed educational environments. Due to the development of mobile technologies, education is no longer restricted to classrooms (Traxler, 2007; Williams & Larwin, 2016). As a result, mobile technologies have taken place in educational environments, and have become an integral part of our lives (Felisoni & Godoi, 2018). In particular, handheld devices have started to be used in mobile learning processes to ensure uninterrupted learning, increase students' participation in the learning process, and ensure student achievement. Programs such as "Bring Your Own Device" (BYOD) (Project Tomorrow, 2012; Song, 2014), which every student can access at any time, both at home, and school, have been put into practice. Thanks to features such as easy accessibility, and portability of mobile technologies, the tendency to use them in educational environments has increased.

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(Tekdal & Saygıner, 2016). With the ease of access to the Internet, the widespread use of mobile technologies, and the increase in the rate of people owning smart devices, mobile technologies have become the primary way of interacting with learning materials (Educause, 2019). The use of mobile technologies has created some promising potential for people, and their lifelong, seamless, and ubiquitous learning etc. For such reasons, mobile technologies have now become a necessity in the education process (O'Bannon & Thomas, 2015).

According to Akkoyunlu, Demirel, and Dağhan (2018) mobile technology is technologies that enable individuals to access, use, store, and share information independently of time, and place, as well as interact, and communicate socially, and culturally (Akkoyunlu, Demirel, & Dağhan, 2018). Mobile learning is about the use of mobile technologies in learning processes. Mobile learning has been defined as learning in multiple contexts through social, and content interactions using mobile electronic devices (Alsaadat, 2017; Crompton, 2013). According to Shih, Chuang, and Hwang (2010), mobile learning is learning performed independently of time, and place with mobile devices loaded with digital content (Shih, Chuang, & Hwang 2010). Easy access to mobile devices, especially mobile phones, increases the interest in mobile learning day by day. Although mobile learning is a new teaching, and learning tool for the education world, it has a bright, and promising future since mobile learning includes students in the education process by offering alternative learning environments (Sönmez, Göçmez, Uygun, & Ataizi, 2018).

Mobile technologies are one of the most frequently used technologies with their ease of use, usefulness, and customizable features (Kavaklı & Yakın, 2019). Low and O'Connell (2006) reported that mobile learning increases flexibility, and gives students a sense of freedom, and responsibility for learning (Low & O'Connell, 2006). Thanks to the advantages of mobile learning, learners can act independently of place, time, and community boundaries (Evans, 2008; Sharples, 2000; Sönmez et al., 2018). Generally, mobile devices are used in studie such as accessing information, reading e-books, listening to podcasts, using learning applications, watching educational videos, playing educational games, accessing documents, attending online classes, taking live lessons, accessing audio libraries, reading asynchronous broadcasts, and joining virtual learning communities (Criollo-C, Guerrero-Arias, Jaramillo-Alcázar, & Luján-Mora, 2021). In the mobile learning process, learners can choose the most suitable material for their needs according to their individual differences. They can take a break whenever they want, and continue as they wish, they can repeat what they learn, and plan their own learning processes (Alsancak Sırakaya, & Seferoğlu, 2018; Sönmez et al., 2018). In other words, while using mobile learning technology, learners can plan, organize, perform, and evaluate their learning because they are the controllers of mobile-based activities. Therefore, the learner is not a passive person who receives the necessary information. The learner is in the position of using cognitive abilities to accomplish the task, and thus developing higher-order thinking skills (McQuiggan, McQuiggan, Kosturko, & Sabourin, 2015). In addition to these, being very rich in terms of interaction enables mobile learning environments to increase their potential. Thanks to this interaction, learners can participate in the teaching process from different places, and become the center of learning action (Kurnaz, 2010). Klopfer, Squire, and Jenkins (2002) reported that the success of mobile learning is based on five characteristics: portability, individuality, usability, connectivity, and social interaction. In addition, Klopfer et al. (2002) stated that mobile learning can meet the immediate needs of students, provide more diversity in terms of the learning environment, and offer faster interactions. Thus, it was reported that learners can increase their own motivation for learning, and achievement.

The use of mobile devices in education brings many difficulties along with many opportunities (Hashemi et al., 2011). The most fundamental challenge is the balanced arrangement of classroom, and out-of-class learning environments (Mierlus-Mazilu, 2010). Moreover, factors such as the mobile e-content design, providing real learning experiences, coming up with a sound pedagogical design, difficulty in understanding, difficulty in using environments, technology acceptance, extra workload, updating information, extra effort, security, and privacy, technical deficiencies of devices, device accessibility, cost, and technological infrastructure, etc. are among the main difficulties in mobile learning. Another important

challenge is distracting conditions in mobile devices (Barry, Murphy, & Drew, 2015; Criollo-C et al., 2011; Hwang & Wu, 2014).

Despite the difficulties mentioned above, mobile learning as a new methodology has developed in a short time, and created new opportunities to strengthen learning (Khaddage, Müller, & Flintoff, 2016). Identifying the best strategies to successfully implement mobile devices is an important issue that requires systematic research (Christensen & Knezenek, 2017). There is a need to do studies on this topic since a great number of studies have been conducted on mobile learning - mainly small-scale - in the education research community. However, the findings of these studies need to be combined to guide further studies (Bano, Zowghi, Kearney, Schuck, & Aubussun, 2018). In recent years, scientists have systematically gathered the findings of mobile learning research to meet this need, and develop a better understanding of how mobile learning supports K-12 learners (Crompton, Burke, & Gregory, 2017; Crompton, Burke, & Lin, 2019; Xie, Basham, Marino & Rice, 2018). In some of these studies, it was aimed to determine the general trend by examining the studies on mobile learning (Kavaklı & Yakın, 2019; Uygun & Sönmez, 2019), while in others, more specifically, the studies on mobile learning in field education were focused on (Bano et al., 2018; Crompton, Burke, Gregory & Gräbe, 2016; Zydney & Warner, 2016).

For example, Xie et al. (2018) reviewed 47 studies on mobile learning from 2007-2016 (Xie et al., 2018). In this study, experimental studies conducted with disabled, and non-disabled students at all grades in formal, and informal K-12 education are discussed. Although there are different variables in different studies, the criteria analyzed in this study can be listed as the participants, the design of the research, the geography of the research, gender, disability of the participants, and the findings of the research. As a result of the systematic analysis, Xie et al. (2018) concluded that many studies focus on the effectiveness of mobile learning in learning, and teaching (Xie et al., 2018), that mixed methods, and experimental studies are the most popular methodologies, and that mobile learning has a positive potential to support the needs of students with disabilities.

In another study, Crompton et al. (2017) examined the studies on mobile learning in the K-12 grades between 2010, and 2015 (Crompton et al., 2017). The criteria analyzed within the scope of research questions can be listed as the aim of the study, research methodology, learning outcomes, fields of study, education levels, educational context (formal, informal), mobile device types, countries studied, and theoretical framework of the research. As a result of this study, in which 113 studies were examined, it was found that most of the studies focused primarily on student learning, and then on system design, mostly worked with primary school students, and in 40% of the studies, mobile learning activities were prepared based on the behavioral approach.

Hwang, and Tsai (2011) analyzed 154 studies published in the Social Science Citation Index (SSCI) database on mobile learning, and ubiquitous learning between 2001-2010 (Hwang & Tsai, 2011). According to the results of the research, it has been stated that research in this field has accelerated since 2008, and when the years 2001-2010 are divided into two periods, the number of articles published in the second period (122) is considerably higher than the number of articles published in the first period (32). According to the fields of study, it has been observed that most studies aren't based on any learning field, but rather focus on students' motivation, perception, and attitudes towards mobile, and ubiquitous learning.

Wu, Wu, Chen, Kao, Lin, and Huang (2012) examined 164 studies on mobile learning published between 2003, and 2010 in their study. The criteria analyzed for research questions in 164 studies include research objectives, research method, and outputs, types of mobile devices used, and types of students, distribution of mobile learning by academic discipline, courses, and highly cited articles. Research findings show that most studies on mobile learning focus on effectiveness, followed by mobile learning system design studies. Survey, and experimental methods were mostly used as research methods. Mobile phones, and PDAs were the most widely used devices in research.

Many "literature research" studies have been carried out on mobile learning, especially after 2010. In these studies, it is seen that the following criteria are generally determined as research criteria: the purpose of the research, research methodology, learning outcomes, education levels, education context, mobile devices used, and countries of study.

In this study, in addition to the basic criteria used in previous literature review studies, criteria such as "reporting the prerequisite tests of the analyzes used in the research", "validity, and reliability studies", "reporting the effect size", and "the existence of ethical, and legal permissions" were also used.

In this context, the study aims to research the studies conducted at the K-12 grades between 2015-2021 on mobile learning, and learning anywhere, and published on "Web of Science" within the scope of certain criteria. Within the scope of this general purpose, the following sub-problems were determined:

1. What are the journals that include studies on mobile learning for K-12 grades, the Q index values (quartile ranks) of these journals, the number of researchers involved in the studies, the distribution of the studies by year and the reporting status of legal and ethical elements?
2. What are the field of the studies, education levels, sample sizes, sampling methods, and the geographical distribution in studies involving mobile learning for K-12 grades?
3. What are the main study objectives, and methodologies in studies involving mobile learning for K-12 grades?
4. Which mobile devices, and mobile learning environments were used in studies involving mobile learning for K-12 grades?
5. What are the dependent and independent variables, and research results examined in studies involving mobile learning for K-12 grades?
6. What is the number of studies that present data collection tools, data analysis methods, prerequisite tests of analyzes (such as normality tests), effect size, and the reliability and validity of data?

2. **Methodology**

A systematic review approach was used to answer the determined research questions of the study, and present, and evaluate the findings from an objective point of view. A systematic review can be defined as selecting, identifying, synthesizing, and combining data from primary research studies to provide a complete, and reliable representation of the subject under review (Kitchenham & Charters, 2007; Oakley, 2012; Uman, 2011). The data collected in the systematic review approach is analyzed to reveal a broader understanding, and trends revealed by the collective data (Sandelowski, Voils, Leeman, & Crandell, 2011). The methods used need to be reproducible, and transparent (NHS Center for Reviews, and Dissemination, 2001).

2.1. *Search Strategy*

The Web of Science (WoS) database, which is a reliable, and competent source for the literature research to be carried out in the first stage of the study, was systematically scanned. Most of the accessed works are in academic databases such as Scopus, ScienceDirect, Wiley Online Library, Springer, Taylor & Francis Online, Sage Journals, rated Digital Library, Emerald, ACM Digital Library, IEEE Xplore, and MDPI. These academic databases are based on previous systematic studies (Alsharida, Hammood, & Al-Emran, 2021; Crompton & Burke, 2020; Diacopoulos & Crompton, 2020; Lai, 2020; Liu, Zowghi, Kearney & Bano, 2021; Masrom, Busalim, Abuhassna & Mahmood, 2021; Moya & Camacho, 2021; Qureshi, Khan, Gillani, & Raza, 2020; Torres-Madroñero, Torres-Madroñero, & Botero, 2020). The terms "mobile learning", "m-learning", "u-learning", "ubiquitous learning" (Chang, Lai, & Hwang, 2018; Lai, 2020) are commonly used to define mobile learning, which is the focus of this review, and some keywords related to

K-12 grades including "preschool" "primary/elementary school", "secondary/middle school", "high school", and "K-12" were searched in the database by using logic operators (i.e. AND and OR), and related results were obtained. The search steps are shown in Figure 1.

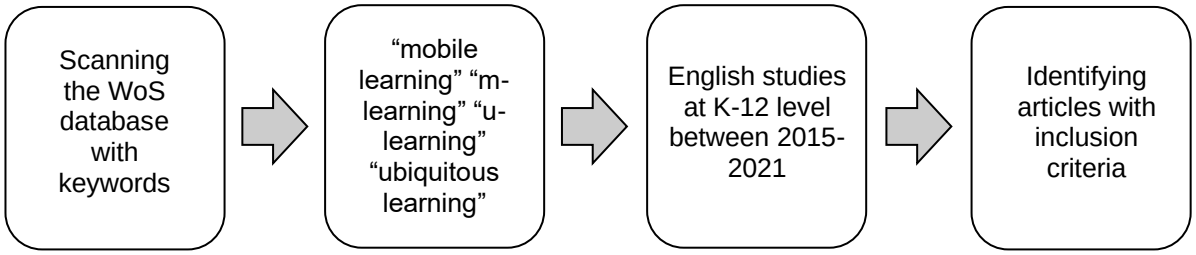

Fig. 1. Search steps

2.2. *Selection of Studies*

This systematic review aims to provide an in-depth perspective on the studies on mobile learning between the years 2015-2021, and reveal the trends. Only studies published in English were included in the searches. When the keywords related to mobile learning were searched in all fields, a total of 4419 studies were found in May 2021. In order to narrow the results, other keywords related to the K-12 grades, which is the scope of the study, were also included in the searches, and 452 studies were found.

2.3. *Inclusion, and Exclusion Criteria*

In this systematic review, the inclusion, and exclusion criteria classified in Table 1 were used. Identified studies were included in this systematic review if they met all inclusion criteria, and did not match any of the exclusion criteria.

Table 1.

Inclusion, and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Covering K-12 grades	Studies covering higher education
Using mobile devices for learning	Studies without mobile devices for learning
Published in 2015 or later	
All fields of study	

After identifying the studies to be reviewed, duplicate studies were removed. The title, summary, and content of all remaining studies were examined. All studies meeting the inclusion criteria of "all kinds of participants at the K-12 grades", and "inclusion of mobile learning" were identified. Their data was entered into an online spreadsheet page. A review of 452 studies resulted in the removal of 336 studies that did not meet the inclusion criteria. As a result, 109 studies were identified as primary studies. Identified studies are listed in Appendix-1. The process of inclusion of studies is given in Figure 2.

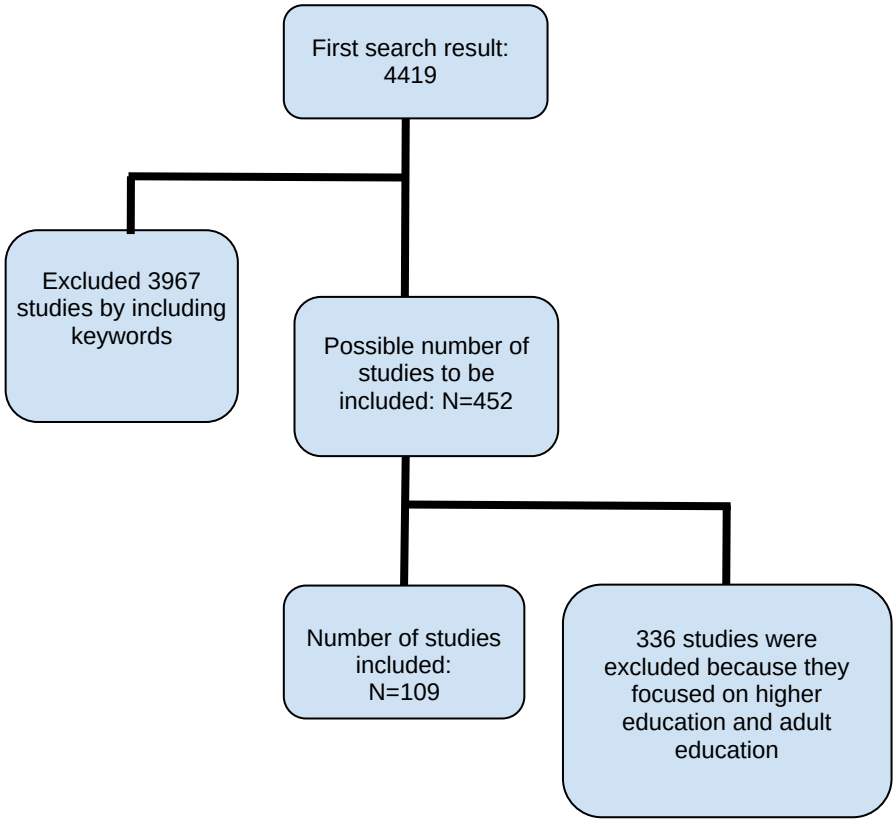

Fig. 2. The process of inclusion of studies

2.4. *Analysis Framework*

Some review criteria were chosen for the analysis of the research questions:

1. Journals
2. Journal Classification
3. Number of Researchers
4. Distribution (of the studies) on the Year Basis
5. Purpose of Research, and Findings
6. Research Methodology
7. Field of Study
8. Education Levels
9. Sample Methodology, and Size
10. Mobile Device Types
11. Operating Systems
12. Mobile Learning Environments
13. Country of Study
14. Dependent, and Independent Variables Examined
15. Prerequisite Tests of Analysis
16. Data Collection Tools
17. Data Analysis Methods
18. Reliability, and Validity of Data Collection Tools
19. Effect Size
20. Legal, and Ethical Permissions

3. **Findings**

3.1. *RQ1*

What are the journals that include studies on mobile learning for K-12 grades, the Q index values (quartile ranks) of these journals, the number of researchers involved in the studies, the distribution of the studies by year and the reporting status of legal and ethical elements?

3.1.1. *Journals in which studies are published*

In this study, a total of 109 publications were examined. The journals with the highest number of publications are given in Table 2.

Table 2.

The Journals with the Highest Number of Publications

Rank	Journal	Number of Articles
1	Journal of Educational Computing Research	8
2	Education and Information Technologies	7
3	Computers & Education	6
4	Computers in Human Behavior	4
5	Educational Technology Research and Development	4
6	Interactive Learning Environments	4
7	British Journal of Educational Technology	3
8	IEEE Transactions on Learning Technologies	3
9	Journal of Educational Technology & Society	3
10	Journal of Science Education and Technology	3
11	Multimedia Tools and Applications	3
12	Others	61

Table 2 shows the journals with the highest number of studies, and the number of publications in these journals, which were determined to be suitable for the criteria as a result of the literature review. Accordingly, 8 studies were identified in the Journal of Educational Computing Research; 7 studies were identified in Education and Information Technologies Journal; 6 studies were identified in Computers and Education Magazine; 4 studies were identified each in Computers in Human Behavior, Educational Technology Research and Development, and Interactive Learning Environments; 3 studies were identified each in the British Journal of Educational Technology, IEEE Transactions on Learning Technologies, Journal of Science Education and Technology, and Multimedia Tools and Applications. A total of 61 studies were identified in 53 other journals.

3.1.2. *Q index values of the journals*

The quartile ranks of the journals included in the literature review are given in Table 3.

Table 3.

Q Index Values of the Journals

Quartile Rank	Number of Journals	Percent (%)
Q1	62	56.9%
Q2	19	17.4%
Q3	9	8.3%
Q4	6	5.5%
No Quartile Rank Yet	13	11.9%

The data in Table 3 are arranged according to the metrics of the Scimago Journal & Country Rank. Accordingly, 62 (56.9%) of the publications identified in the literature review were published in Q1 journals, 19 (17.4%) in Q2 journals, 9 (8.3%) in Q3 journals, and 6 (5.5%) in Q4 journals. 13 journals (11.9%) do not have a quartile rank yet.

3.1.3. *Number of researchers involved in studies*

The data on the number of researchers in the studies included in the literature review are shown in Table 4.

Table 4.

Number of Researchers in Studies

Number of Researchers	Number of Studies	Percent (%)
1	14	12.8%
2	33	30.3%
3	33	30.3%
4	16	14.7%
5	5	4.6%
6	6	5.5%
7	1	0.9%
8	1	0.9%

According to the data in Table 4; studies were carried out with at most 8 (0.9%) researchers, and at least 1 (12.8%) researcher. In addition, studies were mostly conducted by research teams of 2, and 3 people; 33 publications (30.3%) of each were identified. The average number of researchers per publication is 2.93.

3.1.4. *Distribution of the studies by years*

The distribution of mobile learning research included by years is given in Table 5.

Table 5.

Distribution of Publications Included in the Study by Years

Years	Number of Studies
2015	10
2016	11
2017	23
2018	12
2019	26
2020	17
2021	10

According to Table 5, 10 studies published in 2015, 11 published in 2016, 23 published in 2017, 12 published in 2018, 26 published in 2019, 17 published in 2020, and 10 published in 2021 were included in the literature review. The most studies were conducted in 2019, and the least in 2015.

3.1.5. Number of studies reporting legal and ethical elements

Information on legal, and ethical elements in the reviewed articles is given in Table 6.

Table 6.

Distribution of Publications by State of Legal, and Ethical Permissions

Legal and Ethical State	Number of Studies	Percent (%)
Reported	83	76.1%
Not Reported	26	23.9%

As seen in Table 6, while 26 (23.9%) of the publications included in the literature review mentioned legal, and ethical issues, 83 (76.1%) did not convey any information about this situation.

3.2. *RQ2*

What are the fields of study education levels, sample sizes, sampling methods, and the geographical distribution in studies involving mobile learning for K-12 grades?

3.2.1. *Fields of study*

The distribution of the number of publications according to the fields of study is given in Table 8. In some studies, it was seen that studies were carried out in more than one field as displayed in Table 7.

Table 7.

Distribution of Publications by Field of Study

Field	Number of Studies	Percent (%)
Science	27	22.9%
Math	22	18.6%
Foreign Language	20	16.9%
General	20	16.9%
Social Sciences	14	11.9%
Literacy Skills	8	6.8%
Information Technologies and Software	6	5.1%
Photography	1	0.9%

As seen in Table 7, the studies of mobile learning were mostly done in the science field with 27 publications (22.9%). 22 publications were made (18.6%) in mathematics, 20 (16.9%) in foreign language, 14 (11.9%) in social sciences, 8 (6.8%) in literacy skills, 6 (5.1%) in information technologies, and 1 (0.9%) in photography. The number of studies covering the use of mobile technologies in education, not in a specific course, but in school-wide courses, in general, is 20 (16.9%).

3.2.2. *Educational levels*

In Table 8, the distribution of the education levels of the samples according to the number of publications is given. Some studies were conducted on more than one level (primary school-secondary school, secondary school-high school). This information is presented collectively in the table.

Table 8.

Distribution of Publications by Education Levels

Level	Number of Studies	Percent (%)
Primary School	46	38.7%
High School	35	29.4%
Secondary School	32	26.9%
Pre-school	6	5%

According to Table 8, most publications in the mobile learning field were made at primary school with 46 studies (38.7%). It is seen that 35 publications (29.4%) at high school, 32 publications (26.9%) at secondary school, and 6 publications (5%) at pre-school.

3.2.3. *Sample size*

The sample sizes of the publications are also presented in Table 9.

Table 9.

Sample Sizes of Publications

Sample Size	Number of Studies	Percent (%)
0-30	10	9.2%
31-100	56	51.4%
101-200	14	12.8%
201-300	6	5.5%
301-400	2	1.8%
401-500	3	2.8%
501-1000	9	8.3%
1001 and above	6	5.5%

As can be seen in Table 9, the most commonly used sample range is 31-100 (51.4%) followed by 101-200 (12.8%), 0-30 (9.2%), 501-1000 (8.3%), 201-300, and 1001, and above (5.5% each) , 401-500 (2.8%), and 301-400 (1.8%), respectively. Sample size was not specified in three studies.

3.2.4. *Sampling Method*

The sampling methods used in the studies included in the literature review are presented in Table 10.

Table 10.

Sampling Methods Used in Publications

Sampling Methodologies	Number of Studies	Percent (%)
Random Sampling	14	12.8%
Purposive Sampling	5	4.6%
Cluster Sampling	3	2.8%
Random Stratified Sampling	1	0.9%
Convenience Sampling	1	0.9%
Qualitative-Quantitative Sequential Mixed Method Sampling Strategy	1	0.9%
Unspecified	84	77.1%

According to Table 10, the random sampling method is the most frequently used (12.8%) sampling method. Purposive sampling (4.6%), and cluster sampling (2.8%) were the other preferred sampling methods. Random stratified sampling, convenience sampling, and qualitative-quantitative sequential mixed method sampling strategies were used in one publication. 84 studies (77.1%) did not provide information on this issue. However, it is thought that the sampling methods used in these publications were purposive.

3.2.5. *The geographical distribution of studies*

The distribution of the number of publications by country is given in Table 11. In some studies, it was seen that studies were conducted in more than one country (England, USA, Australia, and Germany), and the number of publications of these countries is given separately in the table.

Table 11.

Distribution of Publications by Country

Country	Number of Studies	Percent (%)
Taiwan	25	22.9%
USA	11	10.1%
Indonesia	6	5.5%
Greece	6	5.5%
China	5	4.6%
Israel	5	4.6%
Singapore	5	4.6%
Africa	4	3.7%
Germany	4	3.7%
Hong Kong	3	2.8%
Portugal	3	2.8%
France	2	1.8%
Scotland	2	1.8%
Japan	2	1.8%
Pakistan	2	1.8%
Turkey	2	1.8%
Other	22	20.2%

As can be seen in Table 11, the country with the highest number of studies in the mobile learning field is Taiwan with 25 publications (22.9%). Taiwan is followed by the USA with 11 publications (10.1%), Indonesia, and Greece (5.5%) with 6 publications (5.5%). It is seen that 5 publications (4.6%) were published in this field in China, Israel, and Singapore, 4 publications in Africa, and Germany (3.7%), and 3 publications (2.8%) in Hong Kong, and Portugal. A total of 22 countries with only 1 publication (Denmark, Finland, Croatia, England, Australia, Iran, Ireland, Spain, Sweden, Italy, Canada, Thailand, Mexico, Romania, Saudi Arabia, Brazil, Philippines, Cyprus, Malta, Montenegro, Czech Republic, United Arab Emirates), were included in others. The distribution of the number of publications by continents is presented in Table 12.

Table 12.

Distribution of Publications by Continent

Continent	Number of Studies	Percent (%)
Asia	60	55.05%
Europe	30	27.52%
America	14	12.84%
Africa	4	3.67%
Australia	1	0.92%

According to the data in Table 12, 60 studies (55.05%) were conducted in the Asian continent, 30 studies (27.52%) in Europe, 14 studies (12.84%) in America, 4 studies (3.67%) in Africa, and 1 study (0.92%) in Australia. It is seen that there are many studies on mobile learning in the Asian continent.

3.3. *RQ 3*

What are the main study objectives, and methodologies in studies involving mobile learning for K-12 grades?

3.3.1. *Main study objectives*

Since the research objectives are related to the variables, the dependent variables were analyzed, and the objectives for the 5 most frequently reported dependent variables were determined as follows: 1) Examining the effect of mobile learning on students' achievement. Studies within this scope evaluated the effect of mobile learning on student achievement.2) To investigate the effect of mobile learning on students' learning. Studies within this scope evaluated the effect of mobile learning on student learning. Since some of the studies examined were considered as learning and some as success, these variables were discussed separately in this systematic review. 3) Investigation of students' perceptions of mobile learning. Studies within this scope evaluated students' learning perceptions towards mobile devices. 4) Examining students' attitudes towards mobile learning. Studies within this scope evaluated students' attitudes towards mobile devices. 5) Investigation of students' motivation towards mobile learning. Studies within this scope evaluated the effect of mobile learning on student motivation. The results regarding the coding are given in Figure 3.

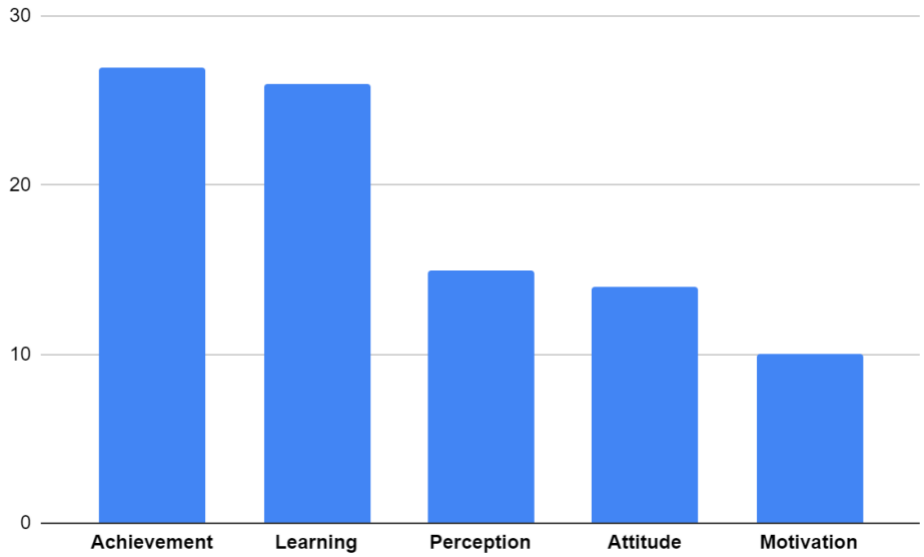

Fig. 3. *Research objectives*

As a result of the coding, it was determined that achievement was the most frequently reported research objective in mobile learning studies with 27 studies (12.2%). Student achievement was evaluated from different perspectives. For example, Tsai, Cheng, Yeh, and Lin (2017) investigated the effects of mobile game-based English learning on student achievement. Zander, Wetzel, and Bertel (2016) developed a mobile application to determine whether the use of touch-based gestures to manually rotate objects increases student achievement for typical mental rotation tasks. Hwang, Utami, Purba, and Chen (2020) examined the effects of mobile fraction learning applications on students' mathematics achievement. Studies from different perspectives are important to gain a more holistic understanding of how mobile learning supports achievement.

Learning was the second most frequently reported research objective in mobile learning studies with 26 studies (11.7%). Student learning was measured by various methods. For example, Liang, Hsu, Hwang, Chang, and Chu (2021) examined the effects of a cooperative game-based learning system with different interaction mechanisms on learning. Choi, Land, and Zimmerman (2018) developed a mobile application for students to learn deeply about the tree life cycle. Tarng, Lin, Lin, and Ou (2016) evaluated the level at which students learned the phases of the moon with their mobile applications containing augmented reality technology. Considering that mobile technologies are used to facilitate students' learning; it is positive that learning is the most common research objective.

Students' perceptions of mobile learning were investigated in 15 studies (6.8%). López-Faican, and Jaen (2020) searched for the change in primary school students' perceptions of basic emotions by integrating mobile augmented reality applications with gamification strategies in their studies. Hao, Lee, Chen, and Sim (2019) evaluated the students' perceptions of this application with their mobile games containing puzzle-solving stories for language learning in their studies. Fabian (2015) examined students' perceptions of a mobile learning application developed for teaching geometry.

Students' attitudes towards mobile learning were explored in 14 studies (6.3%). Arnold et al. (2021), examined the attitudes of preschool children towards the mobile learning application to improve their literacy skills. Changa, Wua, Laia, and Sungb (2015) developed a mobile spatial geometry learning system application to facilitate geometry learning, and evaluated students' attitudes towards the application.

Suswanto, Nidhom, and Putra (2017) developed a mobile application that enables learning computer assembly, and investigated students' attitudes about the application.

The motivation of students for mobile learning was studied in 10 studies (4.5%). Chen, Wang, Zou, Lin, and Xie (2019) examined the motivation of secondary school students to learn English with the interactive mobile geographic map application they developed. Fokides, Atsikpasi, and Karageurgou (2020) used mobile applications to discover primary school students' knowledge, and misconceptions about plants, and they found that these applications increased students' motivation by reducing their misconceptions. Chen (2019) tried to determine whether mobile augmented reality educational materials would increase motivation among students with low, and high anxiety levels for mathematics lessons.

3.3.2. *Research methodologies*

The research methodologies used in the reviewed articles are given in Table 13.

Table 13.

Distribution of Publications by Research Methodologies

Method	Number of Studies	Percent (%)
Experimental	59	54.1%
Survey	10	9.1%
Mixed	20	18.4%
Other	20	18.4%

As seen in Table 13, the most frequently used methodology in studies on mobile learning was the experimental design (54.1%). A mixed design was used in 20 studies (18.4%); survey design was used in 10 publications (9.1%), and designs such as design-based research, case study, comparison research, longitudinal research, evaluation research, scale method, exploratory research, and research-development were used in 20 publications (18.4%).

3.4. *RQ 4*

Which mobile devices, and mobile learning environments were used in studies involving mobile learning for K-12 grades?

3.4.1. *Mobile devices*

The data of the mobile devices used in the studies included in the literature review are presented in Table 14.

Table 14.

Mobile Devices Used in Studies

Mobile Device Type	Percent (%)	Operating System	Percent (%)
Tablet	36.7%	Android	19.6%
Phone	23.4%	iOS	10.8%
Laptop	5.1%	Unspecified	69.6%
Camera	1.9%		
PDA	1.3%		
Unspecified	31.6%		

As can be seen in Table 14, the most preferred mobile devices in the publications in the mobile learning field were tablets (36.7%), and phones (23.4%). Laptop, camera, and PDA were other preferred mobile devices. It is seen that 19.6% of mobile devices use Android, and 10.8% use iOS operating systems. The mobile device type in 31.6% of the publications, and the operating systems of mobile devices in 69.6% of them were not specified.

3.4.2. *Mobile learning environments*

The data of the environments used in mobile devices are presented in Table 15.

Table 15.

Environments Used on Mobile Devices

Environment	Percent (%)
Applications Developed by Researchers	54.1%
Mobile Apps in Stores	33.0%
Unspecified	12.8%

According to Table 15, it is seen that the mobile environments used in the publications in the mobile learning field mostly consisted of applications developed by researchers with 54.1%. While ready-made mobile applications were used in 33% of the studies, data on the mobile environment was not reported in 12.8%. Data on the application type of mobile environments are presented in Table 16.

Table 16.

Application Type of Mobile Environments

Environment Type	Number of Studies	Percent (%)
Gamification Based	24	22.0%
Augmented Reality	11	10.1%
Learning Management System (LMS)	8	7.3%
Programming	3	2.8%
Unspecified	63	57.8%

Table 16 shows that the environment types of the most frequently used applications in the mobile environments of the studies included in the literature review are gamification (22%), augmented reality (10.1%), learning management system (LMS) (7.3%), and programming (2.8%), respectively. In 57.8% of the studies, data on the type of application used was not reported.

3.5. *RQ 5*

What are the dependent and independent variables, and research results examined in studies involving mobile learning for K-12 grades?

3.5.1. *Dependent Variables*

The most frequently used variables, and the number of studies identified in the publications included in the literature review are presented in Table 17.

Table 17.

Most Commonly Used Dependent Variables

Dependent Variable	Number of Studies	Percent (%)
Achievement	27	12.16%
Learning	26	11.71%
Perception	15	6.76%
Attitude	14	6.31%
Motivation	10	4.50%
Usability	8	3.60%
Mobile Application Usage	6	2.70%
Satisfaction	6	2.70%
Performance	6	2.70%
Participation	4	1.80%
View	4	1.80%
Attention and Concentration	4	1.80%
Cognitive Load	4	1.80%
Interest	4	1.80%
Accessibility	4	1.80%
Other	80	36.04%

Table 17 shows that among the dependent variables identified in the literature review, success with 12.16%, and learning with 11.77% are the most frequently used dependent variables in the mobile learning field. In the table, these variables are perception with 6.76%, attitude with 6.31%, motivation with 4.50%, usability with 3.60%, mobile application usage with 2.70%, satisfaction, performance, participation and view with 1.80%. Attention, and concentration, cognitive load, interest, and accessibility. The total percentage of dependent variables used once in publications is 36.04%. Teaching time, student views, language learning, literacy, enjoyment, confidence, self-efficacy, knowledge construction, mobile environment issues, etc. are other dependent variables used.

3.5.2. *Independent Variables*

The most frequently used variables, and the number of studies identified in the publications included in the literature review are presented in Table 18.

Table 18.

Most Commonly Used Independent Variables

Independent Variable	Number of Studies	Percent (%)
Mobile learning application	55	39.29%
Teaching method	15	10.71%
Gender	8	5.71%
Use of mobile technology	8	5.71%
Mobile technology	4	2.86%
Technology integration	4	2.86%
Gamification	2	1.43%
Age	2	1.43%
Grade	2	1.43%
Learning process	2	1.43%
Access to technology	2	1.43%
Other	36	25.71%

As can be seen in Table 18, "mobile learning application" is the most frequently used independent variable with 39.29% of the independent variables determined in the literature review. This variable is followed by teaching method with 10.71%, gender, and mobile technology use with 5.71%, mobile technology, and technology integration with 2.86%, gamification, age, grade, learning process, and access to technology with 1.43%. The total percentage of independent variables used once in publications is 25.71%. Acceptance of mobile learning, education, location, interaction, instructional design, collaboration, captioning, videoconferencing, technology ownership, learning styles, feedback, and frequency of mobile application usage, etc. are other independent variables used as well.

3.5.3. *Research results*

The findings obtained from the analysis of the dependent variables examined in the studies are given in Table 19.

Table 19.

Research Results Obtained from the Analysis of Dependent Variables

Variables	Positive (%)	Negative (%)	Neutral (%)
Achievement	89.5	0.0	10.5
Learning	96.2	0.0	3.8
Attitude	64.3	7.1	28.6
Mobile Application Usage	100.0	0.0	0.0
Motivation	100.0	0.0	0.0
Satisfaction	100.0	0.0	0.0
Perception	100.0	0.0	0.0
Usability	100.0	0.0	0.0
Performance	100.0	0.0	0.0
View	100.0	0.0	0.0

Table 19 shows that student achievement in mobile learning has a positive result at a rate of 89.5%, and no difference was detected at a rate of 10.5%. It was determined that 96.2% of the studies investigating learning had positive results, and no difference was found at the rate of 3.8%. It was reported that studies examining student attitudes reported positive 64.3%, negative reports 7.1%, and no difference detected 28.6%. In all studies investigating mobile application usage, motivation, satisfaction, perception, usability, performance, and views, completely positive results (100%) were obtained.

3.6. *RQ 6*

What is the number of studies that present data collection tools, data analysis methods, prerequisite tests of analyzes (such as normality tests), effect size, and the reliability and validity of data?

3.6.1. *Data collection tools*

Information on the data collection tools used in the reviewed articles is given in Table 20.

Table 20.

Distribution of Data Collection Tools by Frequency of Use

Data Collection Tools	Frequency of Use	Percent (%)
Questionnaire	51	46.8%
Likert Type Scale	45	41.3%
Post-test	44	40.4%
Pre-test	37	34%
Interview	38	34.9%
Test	28	25.7%
Observation	19	17.4%
Achievement Test	17	15.6%
Application Usage Data	12	11%
Form	11	10.1%
Open-Ended Question	8	7.4%
Video (During Application Usage)	5	4.6%
Rubric	3	2.8%

Inventory	3	2.8%
Ethnography	1	0.9%

In some studies, it was observed that more than one data collection tool was used. According to the data in Table 20; Questionnaire in 51 (46.8%), Likert-type scale in 45 (41.3%), post-test in 44 (40.4%), pre-test in 37 (34%), and interview in 38 (%34.9) were the most used data collection tools. These tools are followed by various tests with 25.7%, observation with 17.4%, achievement test with 15.6%, and application usage data (application interactions) with 11%. Forms, open-ended questions, video recordings taken during the application, rubrics, inventory, and ethnography are other preferred data collection tools.

3.6.2. *Data analysis methods*

The data analysis methods included in the studies are presented in Table 21.

Table 21.

Data Analysis Methods Used in Publications

Data Analysis Method	Number of Studies	Percent (%)
Descriptive	102	40.8%
Predictive	88	35.2%
Qualitative	46	18.4%
Other	14	5.6%

As seen in Table 21, the most used data analysis method in mobile learning research is descriptive analysis (40.8%). Descriptive analysis method is followed by predictive (35.2%), and qualitative analysis methods (18.4%), respectively. Correlation, regression, variance, and factor analysis were used in 14 studies (5.6%). In most of the studies, it was seen that more than one data analysis method was used together.

In Table 22, the details of the data analysis methods used in these studies are given.

Table 22.

Detailed Representation of Data Analysis Methods Used in Publications

Data Analysis Methods	Experimental Studies				Survey Studies				Other Studies				
	Descriptive	Predictive	Qualitative	Other	Descriptive	Predictive	Qualitative	Other	Descriptive	Predictive	Qualitative	Other	Sum
ANOVA		15								2			17
Mean/Standard Deviation	42								20				62
MANOVA		6								2			8
T-test		20								8			28
Comparative Data Analysis		3											3
Analysis of Variance				2								1	3
Levene Test		1											1
ANCOVA		11											11
Correlation Analysis				3				1				2	6
F test		1											1

Frequency/Percentage/Chart	10				3				14				27
Descriptive Analysis			22		5						24		51
Factor Analysis				1				1				1	3
Nonparametric Tests		13								6			19
Graphical Representation	4				1				3				8
Regression Analysis				1								1	2

As seen in Table 22, the three most used data analysis methods in studies on mobile learning examined within the scope of the research are mean/standard deviation, and descriptive analysis as descriptive analysis methods, and t-test as a predictive analysis method. Then, it is seen that frequency/percentage/chart, non-parametric tests, ANOVA, and ANCOVA are preferred.

3.6.3. Numbers of prerequisite tests (such as normality tests) of analyzes

Information on studies reporting prerequisite tests in publications included in the literature review is given in Table 23.

Table 23.

Distribution of Publications by Reporting Status of Prerequisite Tests of Analysis

Status of Prerequisite Tests of Analysis	Number of Studies	Percent (%)
Reported	52	47.7%
Not Reported	57	52.3%

According to Table 23, the number of publications reporting the prerequisite tests of the analyzes is 52 (47.7%); 57 studies (52.3%) did not provide information on this issue.

3.6.4. *Effect size been reported in studies*

The findings regarding the effect size in the reviewed publications are given in Table 24.

Table 24.

Distribution for Reporting Effect Size

Effect Size	Number of Studies	Percent (%)
Reported	20	18.3%
Not Reported	89	81.7%

As seen in Table 24, 20 (18.3%) of the publications included in the literature review reported effect size, while 89 (81.7%) did not.

3.6.5. *Reliability, and validity information of data collection tools*

Table 25 presents the distribution of the reviewed publications for reporting the validity, and reliability analyzes of the data collection tools.

Table 25.

Distribution of Validity, and Reliability Studies of Data Collection Tools

Status of Validity, and Reliability Studies of Data Collection Tools	Number of Studies	Percent (%)
Reported	44	40.4%
Not Reported	65	59.6%

According to Table 25, it is seen that 44 publications include validity, and reliability studies on data collection tools, while 65 publications do not include information on validity, and reliability studies.

4. Conclusion and Suggestions

Within the scope of this systematic review, 109 publications were analyzed. The study presented various findings about the publications conducted on mobile learning in K-12 grades; purposes, methods, results, fields of study, education levels, samples, mobile device types, and environments, the geographical distribution of publications, dependent, and independent variables examined, analyzes used, and prerequisite tests, data collection tools, reliability, and validity information of these tools were also examined. It provides an up-to-date synthesis of data analysis methods, journals with publications, the number of researchers participating in the studies, the distribution of studies by years, effect sizes, and reporting of ethical, and legal permissions.

It has been determined that mobile learning studies are generally carried out with small research groups, and are mostly published in journals in the Q1, and Q2 quarters. It can be stated that the studies are carried out by small research groups with skills, and experience in the field so that qualified reports contributing to the literature are presented to the academic community. It can be said that studies on mobile learning have generally increased in recent years. Considering the potential contributions of mobile devices to learning, it can be stated that this is a positive situation.

The main aims of the studies include the examination of variables such as learning, achievement, perception, attitude, motivation, and educational psychology. To investigate these, mostly experimental methods (54.1%), and mixed methods (18.4%) were used. It has been determined that experimental study methodologies have evolved into more sophisticated, and complex structures. Wu et al. (2012) reported that surveys, and experimental methods were mostly used as research methods in studies. Chee, Yahaya, Ibrahim, and Noor Hassan (2017) shared the finding that quantitative research methods are most frequently used in research on mobile learning. Xie et al. (2018) also concluded that mixed methods, and experimental methods are the most popular methodologies for examining variables in many studies. Mixed-methods research can address different questions simultaneously with both qualitative, and quantitative approaches, and provide a diversity of opinions (Teddlie & Tashakkori, 2009). Findings regarding methodologies in this systematic review are consistent with previous studies. In this respect, future studies with mixed methods may offer a richer understanding to reveal related phenomena. In addition, very positive results were obtained in the studies examined. Similarly, most of the previous studies in the literature had positive results for mobile learning (Crompton & Burke, 2018; Crompton & Burke, 2015; Lai, 2020; Qureshi et al., 2020; Sung, Chang & Liu, 2016; Wu et al., 2012). Some variables such as students', and teachers' previous experiences with mobile devices, the frequency of students' use of mobile devices, and the effect of innovation may have an impact on the investigated phenomena. Therefore, studies dealing with more variables that may be related to the mobile learning context may contribute to the explanation of the high rate of positive reports in a holistic structure.

It has been determined that the science, mathematics, and foreign language fields are mostly included in the mobile learning studies carried out in the K-12 grades. The widespread selection of the fields of study that require more cognitive load during learning may contribute to a better explanation of the findings reporting the positive effects of mobile learning tools on students' performance. It can be stated that experimental studies that usually involve grade participation are designed, and studied with small samples. It is seen that 60% of the studies were conducted with less than 100 participants. In addition, it was determined that 9.2% of the studies were conducted with less than 30 participants. It is thought that this situation may lead to external validity problems. Sung, Lee, Yang, and Chang (2019) reported in their review that 44% of mobile learning studies were conducted with 31 to 50 participants in each group, and about 40% with less than 30 participants in each group. Cheung, and Slavin (2013), and Pagano (2007) state that a sample in the range of 0-30 will lead to insufficient statistical power. In 77.1% of the studies, there is no information about how the sample was selected. It has been determined that the number of studies conducted mostly at primary school (38.7%), secondary school (26.9%), and high school (29.4%) is close to each other. However, it was determined that mobile learning studies covering the pre-school period were very few (5%). The increase in studies covering the pre-school period may contribute to increasing awareness that younger age groups can use mobile devices for various learning tasks. In addition, researching mobile learning in the preschool period will contribute to illuminating many dark points for the academic community, and determining the focus of research. Researchers can be encouraged to carry out studies such as digital literacy for more efficient use of mobile devices at preschool.

Although the type of mobile device used in 31.6% of the studies was not specified, mostly tablets (36.7%), and smartphones (23.4%) were used in mobile learning activities. Wu et al. (2012) reported that mobile phones, and PDAs are the most widely used devices. Crompton et al. (2016) also reported that the most commonly used devices in their study were PDAs (30%), and mobile phones (30%). Our findings revealed that PDAs have been replaced by tablets with the effect of technological developments, and mobile learning experiences have changed in recent years. Mobile applications (54.1%) developed by researchers were mostly used in the studies. This was followed by mobile applications (33%) downloaded from application stores. Analysis of mobile application types revealed that gamification-based mobile applications (22%), mobile applications with augmented reality (10.1%), and learning management systems (7.3%) are frequently used. In 57.8% of the studies, the researchers did not report what kind of mobile applications they used.

It has been determined that the country with the highest number of studies on mobile learning is Taiwan (22.9%), followed by the USA (10.1%). In addition, it was determined that 55.05% of the publications were conducted in the Asian continent, 27.52% in the European continent, and 12.84% in the Americas. Similar results were obtained in previous systematic reviews (Crompton & Burke, 2018; Crompton et al., 2016; Hwang & Tsai, 2011; Lai, 2020; Liu, Scordino, Geurtz, Navarrete, Ko & Lim, 2014). Taiwan was always among the countries where mobile learning studies are carried out the most. In this systematic review, 8 (32%) of 25 studies identified as having been conducted in Taiwan covered learning English as a foreign language, and 7 (28%) covered science subjects. In addition, it was determined that 8 studies (32%) were conducted in learning management systems, and 5 studies (25%) were carried out in game-based mobile application environments. Tablets were used in 15 (60%) of the studies conducted in Taiwan.

The most examined dependent variables in studies are learning, achievement, perception, attitude, motivation, usability, mobile application usage, satisfaction, performance, participation, opinion, attention, and concentration, cognitive load, interest, and accessibility. The most examined independent variables are mobile learning application, teaching method, gender, mobile technology use, mobile technology, technology integration, gamification, age, class, learning process, and access to technology. Most of the studies investigated the impact of various strategies, and technologies related to mobile learning on learning. In Hwang, and Tsai's (2011) review, it was stated that the studies focused more on students' motivation, perception, and attitudes towards mobile, and ubiquitous learning.

Regarding the analyses made in the studies, the number of studies reporting prerequisite tests was 52 (47.7%). Prerequisite tests were not reported in 57 studies (52.3%). Ghasemi, and Zahediasl (2012) stated that there is at least one statistical error in approximately 50% of the articles published, and that the assumption of normality should be checked to ensure the validity of many statistical procedures such as parametric tests. Most parametric tests, such as t-tests, correlation, analysis of variance, and regression analysis, assume that the data are normally distributed. Therefore, parametric tests by researchers without making sure that the prerequisites of the tests are met may lead to erroneous findings. The sample size discussed in the previous sections also has a significant impact on prerequisite tests. Therefore, choosing the prerequisite tests suitable for the sample size, and analyzing the data according to the statistical results will reduce the threats to internal validity in the studies. In this respect, it can be stated that there are important deficiencies regarding sample sizes, and reporting of prerequisite tests in the articles examined.

It was determined that more than one data collection tool was used in the studies. Apparently, the most frequently used data collection tools were questionnaires, Likert-type scales, posttests, pretests, interviews, tests, and observations. In 59.6% of the studies, no information was given about the reliability, and validity of the data collection tools. Büyüköztürk, and Kutlu (2006) stated that the first rank among the most frequently encountered problems in conducted studies is that the processes for validity, and reliability are not adequately explained. It has been determined that the most used analysis methods are descriptive statistics, relational analysis, and qualitative analysis. In addition, it can be stated that researchers do analyses using various statistical methods. The findings we obtained in the context of data analyzing methods position our study covering the K-12 grades differently from some previous systematic reviews. In Lai's (2020) study, it was stated that the most frequently used analyzing methods were t-test, and ANOVA/ANCOVA, and it was stated that few studies gave descriptive results. In this respect, future extensive research on mobile learning studies may contribute to a better understanding of the nature of mobile learning research.

While a small portion of the publications included in the literature review reported the effect size, in most studies (81.7%) the effect size was not reported. In their systematic review study, Sung et al. (2019) reported that approximately 70% of existing mobile learning studies did not provide effect sizes for research results (Sung et al., 2019). This result suggests that researchers only focus on the importance of statistical tests. American Psychological Association (2001) stated that effect sizes should always be reported together with p significance values. To interpret statistical test results, it may not be sufficient to look only at the significance levels. Researchers should put more effort into reporting effect sizes, bearing in mind that although the test result may be significant, the effect may be low.

Legal, and ethical permissions were mentioned in only 26 (23.9%) of the reviewed studies. Yip, Han, and Sng (2016) stated that situations such as not obtaining ethical review approval, lack or incomplete informed consent, and failure to protect confidentiality are considered research abuses according to international guidelines, and regulations. Therefore, researchers are expected to be more sensitive about legal and ethical issues.

5. **Future Research**

This systematic review of mobile learning studies in the K-12 grades includes some suggestions for future research. There is a need for more studies that reveal the contributions of mobile learning to students' achievement, learning levels, and learning processes in different fields of study. At this point, the potential power of mixed pattern research can be utilized. It can be stated that there are very few mobile learning studies covering the pre-school period. It would be beneficial to carry out studies that could contribute to filling the big gap here. It would also be beneficial to control internal validity threats, such as the novelty effect, which may have had an impact on the variables examined in studies. In order to eliminate both internal, and external validity threats in the studies, researchers are expected to work with larger sample

sizes, use tools such as G*Power to select adequate sample sizes, to perform reliability, and validity analyses of the data collection tools they will use, to perform prerequisite tests (such as normality test) to choose the right data analysis tests, and to report effect sizes, They are expected to obtain legal, and ethical permissions. It is important to take the necessary precautions regarding the situations we mentioned, and report them transparently, and meticulously in the studies. The fact that reports that meet certain standards will provide academic readers who review these studies with better guidance in the design, conduct, and reporting of scientific research.

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