A taxonomy of mobile learning based on a systematic review

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Abstract: This study seeks to deepen the understanding of existing mobile learning research, summarize the relevant knowledge, and identify research gaps. This study is based on a systematic review of relevant studies conducted between 2009 and 2018; the final pool of studies comprised 25 studies, representing a total of 1828 original academic publications. A taxonomy was proposed based on 13 taxonomies, which were grouped into five domains: bibliometric statistics; research purposes; demographics and context; methodologies; and outcomes. The findings revealed the following: the number of articles published has increased over the last years, with significant contributions from Asia; most studies feature positive outcomes; the main focus is on learning effectiveness; the majority of the target sample comprises students, and the environment is hybrid, with a tendency to be informal; and mixed research methodologies are the common trend. The results also revealed a lack of current research in the field of strategies and frameworks, a common thread among all these studies.

Keywords: mobile learning; taxonomy; science education; systematic review.

1 Introduction

1.1 Theoretical background

Learning innovation in quality education includes digital approaches as catalytic converters that enhance learning and contribute to the development of 21st-century skills.

According to a 2016 Mckinsey study, "How to scale personalized learning", schools face the significant challenge of having to develop learning experiences to prepare students for the labour market, even if half of the jobs are expected to disappear in the future. Almost 40 percent of employers say a lack of skills is the main reason for entry-level vacancies (Mourshed, Farrell, & Barton, 2013). To make matters more complicated, work has also evolved from a requirement for basic technical knowledge to a demand for high multiple skilled workforces. Technological progress, infrastructure deployment, and falling prices have brought unexpected growth in digital access and connectivity to billions of people around the world. The extensive and ordinary use of mobile devices means it is feasible to have at least one device connected at any time, i.e., "1:1, 24x7" connectivity (Wong & Looi, 2011). Simultaneously, the advancement in mobile technologies and mobile applications has been unprecedented (Y.-C. Hsu, Rice, & Dawley, 2012).

Mobile learning positive outcomes have been researched in multiple studies (Churchill & Churchill, 2008; Frohberg, Göth, & Schwabe, 2009; Hwang & Tsai, 2011; Krull & Duart, 2017; Liu et al., 2014; Wong & Looi, 2011). Additionally, the Program for International Student Assessment (PISA) revealed a strong correlation between the availability of technology in schools and the students' performances in general (4). Although most of the research has been oriented to students, the literature also proves positive results in teachers (Baran, 2014).

Despite the availability of mobile learning projects, tools, strategies, models and frameworks and the development of a consensus over last years about positive outcomes and the need to make education more digital, a considerable number of schools are still quite analogical. Some authors argue that mobile learning adoption has been slow and limited and has often focused on facilitating the delivery of content rather than on the optimization of mobile learning potential (Keengwe, Onchwari, & Wachira, 2008; Niemi, Kynäslahti, & Vahtivuori-Hänninen, 2013; Voogt, Knezek, Cox, Knezek, & ten Brummelhuis, 2013). "Mobile learning adoption into mainstream education has been slow" (Alrasheedi & Capretz, 2015)..

There is a need to evolve on a solid and consistent basis to close the gap between the amount of technology available and the use of that technology (Kopcha, 2012; Nikolopoulou & Gialamas, 2016; Rikala, 2015; Stevenson, Hedberg, O'Sullivan, & Howe, 2015) and to evolve towards a sustainable integration of mobile learning (Miltenoff, Keengwe, & Schnellert, 2013; Ng & Nicholas, 2013; Rikala, 2015).

One of the main challenges to conducting a rigorous analysis is the diversity and lack of consistency in the classification and methodological coding of the main aspects of the field. Up to 99 different categories used by leading authors in the field of mobile learning have been identified.

1.2 Literature review

There are numerous studies defining mobile learning, and most of them highlight its core characteristics. The literature reveals consensus on mobile learning affordances,

including flexible use, ubiquity, anytime-access, portability, continuity of use, timely feedback, just-in-time learning, personalization, socialization, active participation, peer coaching, self-evaluation, interactive convenience from the real world, multimodal re-presentation of learning experiences, sources of inspiration outdoors and cultural authenticity (Baran, 2014; Dalziel et al., 2016; Krull & Duart, 2017; Kukulska-Hulme & Viberg, 2018; Liu et al., 2014; Pimmer, Mateescu, & Gröhbiel, 2016; Rikala, 2015; Wu et al., 2012). To define mobile learning, some authors focused on the device type, software and networks (Keengwe, 2007; Kukulska-Hulme & Viberg, 2018). Other authors highlighted technological and pedagogical aspects: "mobile learning involves the use of wireless-enabled mobile digital devices, within and between pedagogically designed learning environments or contexts" (Cochrane & Bateman, 2010, p. 2). Wu et al. (2012) defined that mobile learning is characterized by learners engaged in educational activities in which technology is used as a mediating tool for learning via mobile devices accessing data and for communicating with others through wireless technology. Hwang and Tsai (2011) defined mobile learning as using mobile technologies to facilitate learning, while a popular definition of ubiquitous learning is "learning anywhere and at any time" (Hwang, Tsai, & Yang, 2008, p. 4). Rikala (2015) defined mobile learning as the art of using mobile technologies to empower and enhance learning experiences. In terms of a pedagogical approach, most of the research agree that mobile learning strategies include fundamentals based on the constructivist learning perspective that sees learning as a process of reconstruction rather than as the transmission of knowledge (Papert & Harel, 1991). Based on the social constructivist learning theory, mobile learning also has proven successful in leveraging the collaborative affordances of social media (Fu & Hwang, 2018). According to (Pimmer et al., 2016), studies that involve hybridization by connecting situated, constructionist and collaborative learning provide convincing arguments for what is viewed as the core of mobile learning (Sharples, Taylor, & Vavoula, 2010).

The concept evolves in parallel with new affordances. Recently, mobile learning is included in seamless learning that refers to the seamless integration of the learning experiences across different contexts including formal and informal, individual and social, and, physical and virtual (Y.-C. Hsu & Ching, 2015; Looi et al., 2010; Wong & Looi, 2011). Additionally, social media has gained ground with a growing recognition of mobile learning's significant role: "mobile learning is learning across multiple contexts through social and content interaction using personal electronic devices" (Crompton & Burke, 2018, p. 2). Koole (2009) defined mobile learning as a process resulting from the convergence of mobile technologies, human learning capacities, and social interaction.

Sharples and Pea (2014) identified three phases in the evolution of mobile learning: i) a focus on mobile devices, ii) learning outside the classroom, and iii) student mobility and information. Similarly, Koole, (2009) identified three aspects of mobile learning: device, student and social aspects. Mobile learning has evolved through three dimensions: technological, pedagogical and social aspects. Likewise, mobile learning strategies have become more sophisticated and broadened in accordance with pedagogical strategies and the evolution of the social dimension in society. Lai and Hwang (2015) identified ten mobile learning strategies: guided learning; peer assessment; video sharing; synchronous sharing; issue-based discussion; computers as mindtools;

project-based learning; inquiry-based learning; contextual mobile learning; and game-based learning.

1.3 Purposes of this study

This study attempts to investigate the existing mobile learning research, summarize and organize the relevant knowledge, and to consolidate the basis for its adoption and sustainable development. Specifically, the present review was guided by the following research questions, all of them considering the 2009-2018 period:

1. Why is mobile learning research relevant? In moderating mobile learning, what are the main bibliometrics and statistics, including the development trend of the number of academic publications, sources of academic publications, citations and geographical distribution.
2. What knowledge has been investigated? What are the dominant research purposes related to mobile learning?
3. Who is and where is the target? What are the key research demographics and context: sample type; educational levels; sample size; learning domains; learning context; and devices used?
4. How has the research been conducted? What are the major research designs and methodologies in the mobile learning field?
5. What are the main outcomes in the studies of mobile learning?

2 Method

2.1 Research design

A systematic review (Hemingway & Brereton, 2009) approach was performed in this study to answer the five research questions directing this study, with the goals of providing an impartial synthesis, summarizing and generalizing the relevant knowledge trends, as well as identifying and prospecting for patterns, gaps and interpreting the findings. A systematic review was shown to be the appropriate scientific method to address these issues (Bhat & Al Saleh, 2015; Crompton & Burke, 2018; Fu & Hwang, 2018; Kaliisa & Picard, 2017; Krull & Duart, 2017). To ensure that the review process is rigorous and valid, a detail process protocol was followed. There are several protocols for conducting a systematic review (Cook & West, 2012; Meca, 2010). Combining and adjusting these processes, the following five step protocol was followed: 1) formulating the problem and defining the focus question, 2) searching for the literature and deciding on the inclusion and exclusion criteria, 3) defining taxonomies and coding the studies 4) conducting the statistical analysis and developing results 5) and interpreting the findings.

Following the above described process, the first phase was to formulate the problem. This study attempts to investigate the current status of mobile learning research, summarize relevance, trends, most investigated knowledge, demographics, methodologies, and outcomes, and identify research gaps.

2.2 Inclusion and exclusion criteria

The second phase of the systematic review process described in section 2.1 is related to research for the literature. The inclusion and exclusion criteria used to filter academic publications gathered from digital databases were defined based on the research questions guiding this research:

1. Mobile learning, ubiquitous learning, and Mlearning or blended learning were among the key variables of the study. The studies must have been published between 2009–2018.
2. The study design was quantitative (descriptive, comparative, quasi-experimental, experimental), and the methodology comprised a meta-analysis or systematic review.
3. The outcomes were robust, clearly defined, scientifically traceable, plausible and relevant.
4. The studies must have been published in a peer-reviewed, internationally oriented journal.

Studies were excluded based on the following criteria: 1) they did not focus on learning, education or adopting educational purposes, 2) the articles were based on original research.

2.3 Search strategy and retrieval of studies

The search of the literature was based on a concept-centric approach (Okoli & Schabram, 2010; Webster & Watson, 2002). For literature reviews conducted in relation to education, the Web of Science database has been recommended by several previous studies (Fu & Hwang, 2018). In the search of the literature in the database, the expressions ("mobile learning" OR "ubiquitous learning" OR "blended learning" OR "M-learning" OR "B-learning" OR "mobile devices") AND ("systematic review" OR "meta-analysis" OR "trends") were used as keywords.

The research process initially yielded 599 publications. Based on titles, 48 were filtered; in reading the abstracts, keywords were re-vised and refined. The article grouping was adjusted and summarized in meta-data, and based on the inclusion and exclusion criteria, a concept matrix was developed for the selected studies. A total of 30 full-texts were screened by the two authors, and based on the criteria, 25 were identified as eligible for the review and were comprehensively analysed. The differences in the interpretation were resolved upon discussion. Figure 1 shows the data search and collection process.

Figure 1 Diagram of the literature search process

The final pool of studies comprised 25 studies, representing a total of 1828 original academic publications.

3 Research Results and Discussions

The research results include the third and fourth steps of the systematic review process described in section 2.1: 3) defining the taxonomies and coding the studies and 4) conducting the statistical analysis.

3.1 Taxonomies and coding

Based on the process described in section 2.1, the third step in concluding a systematic review is to identify the main taxonomies by which to structure, organize, and codify the research. For that purpose, a content analysis methodology was used. In the analysis of documents, content analysis is a method that enables the researcher to test theoretical issues to enhance the understanding of the data (Elo & Kyngäs, 2008). Content analysis

can use a mix of quantitative and qualitative methods so that a combination of bibliometric and categorical data can be used to reveal trends (Wu et al., 2012).

For addressing the advancement of mobile learning, all the selected studies focused on a particular set of issues by using a wide variety of names: categories, dimensions, super dimensions, subdimensions, variables, components, and features. Combining all 25 studies, the resulting number of categories analysed was 99. The 25 studies included in this research analysed a mean of 7.32 different categories, ranging from 2 to 12 categories. Only one study analysed two categories (Alrasheedi & Capretz, 2015), and three studies analysed 12 categories (Krull & Duart, 2017; Zheng, Li, Tian, & Cui, 2018). The results of the distribution analysis showed a high probability density around the mean number of categories 7.32. The standard deviation was 2.85. Figure 2 shows the distribution and the mean of the categories included in the analysed studies.

Figure 2 Distribution of the number of categories analysed in the mobile learning research from 2009 to 2018

Figure 3 shows the sample size of the 25 studies included in this research. There is no significant correlation between the size of the original sample of the studies included in this research and the number of categories; the overall correlation coefficient, r, was 0.21.

Figure 3 Distribution of the sample size in mobile learning research from 2009 to 2018

The number of categories analysed over the years has been significantly stable. The correlation between the number of categories and the number of years has not been found, as $r = 0.28$.

Based on the contents of each study, the original 99 categories were analysed, filtered and assembled into thirteen categories. Table 1 shows the categorization of the original items analysed in the studies.

Table 1 List of categories included in the mobile learning research from 2009 to 2018

Category	*Original extracts*	*# St*	*Studies*
Citations	Citations	2	(Bhat & Al Saleh, 2015; Wu et al., 2012)
Countries / region	Countries; Region; Country context; Geographical spread; World region	9	(Chee, Yahaya, Ibrahim, & Hasan, 2017; Crompton & Burke, 2018; J.-L. Hung & Zhang, 2012; Hwang & Tsai, 2011; Kaliisa & Picard, 2017; Krull & Duart, 2017; Liu et al., 2014; Virtanen, Haavisto, Liikanen, & Kääriäinen, 2018)
Data collection methods	Data sources; Data Collection	7	(Cheung & Hew, 2009; Crompton & Burke, 2018; Kaliisa & Picard, 2017; Krull & Duart, 2017; Virtanen et al., 2018; Wu et al., 2012; Zheng et al., 2018)
Devices	Types of mobile devices; Technology used; device used; Mobile handheld devices; Mobile devices adopted; Hardware	14	(Baran, 2014; Bhat & Al Saleh, 2015; Chee et al., 2017; Cheung & Hew, 2009; Crompton & Burke, 2018; Fu & Hwang, 2018; Kaliisa & Picard, 2017; Krull & Duart, 2017; Liu et al., 2014; Y.-T. Sung, Chang, & Liu, 2016; Tingir, Cavlazoglu, Caliskan, Koklu, & Intepe-Tingir, 2017; Wu et al., 2012)

Distribution trend	Trends in m-learning; distribution across years; distribution status; trends in m-learning; number of articles; growth of m-learning research; histogram; distribution by year	6	(Chee et al., 2017; J.-L. Hung & Zhang, 2012; Hwang & Tsai, 2011; Liu et al., 2014; Y.-T. Sung et al., 2016; Wu et al., 2012)
Educational levels	Educational levels; Learning Stages; Participants; Subjects; Sample Institution; Learning stage; grade level; Subjects; Sample Groups; Population Groups; Participants	5	(Chee et al., 2017; Crompton & Burke, 2018; Fu & Hwang, 2018; Hwang & Tsai, 2011; Krull & Duart, 2017)
Journals	Periodic journal contribution; rank and title of the journal; prolific journals; major research journals; well-recognized journals; distribution of journals; journal list (in frequency order)	7	(Chee et al., 2017; Crompton & Burke, 2018; J.-L. Hung & Zhang, 2012; Hwang & Tsai, 2011; Hwang & Wu, 2014; Krull & Duart, 2017; Liu et al., 2014)
Learning domain	Subject Domain; Learning Domain; Subject Matter Domain; Learning subjects; Academic Disciplines; Subject Area; Disciplines and Courses	11	(Baran, 2014; Chee et al., 2017; Crompton & Burke, 2018; Fu & Hwang, 2018; Hwang & Tsai, 2011; Hwang & Wu, 2014; Krull & Duart, 2017; Y.-T. Sung et al., 2016; Tingir et al., 2017; Wu et al., 2012)
Learning environment	Educational context; sample group; environments of mobile learning applications; situated action context; research settings	13	(Bhat & Al Saleh, 2015; Chee et al., 2017; Crompton & Burke, 2018; Frohberg et al., 2009; Fu & Hwang, 2018; Krull & Duart, 2017; Y.-T. Sung et al., 2016; Virtanen et al., 2018; Wu et al., 2012),(Zheng et al., 2018)
Outcomes	Learning outcome knowledge and satisfaction; Measured outcomes	10	(Bhat & Al Saleh, 2015; Chee et al., 2017; Crompton & Burke, 2018; Hwang & Wu, 2014; Liu et al., 2014; Mahdi, 2018; Pimmer et al., 2016; Y.-T. Sung et al., 2016; Wu et al., 2012; Zheng et al., 2018)
Research methods	Methodology; Method; Research design; Research methodology; Design; Study designs	5	(Chee et al., 2017; Fu & Hwang, 2018; Kaliisa & Picard, 2017; Krull & Duart, 2017; Zheng et al., 2018)
Research purposes; focus	Research Purposes; Focus	8	(Al-Zahrani & Laxman, 2016; Chee et al., 2017; Cheung & Hew, 2009; Crompton & Burke, 2018; Fu & Hwang, 2018; J.-L. Hung & Zhang, 2012; Krull & Duart, 2017; Wu et al., 2012)
Sample size	Sample size, group size	2	(Fu & Hwang, 2018; Zheng et al., 2018)

The learning environment and devices are the categories most studied, while citations and the sample size the ones less analysed. Figure 4 depicts the number of articles that comprised each of the thirteen categories identified in this study.

Figure 4 Distribution of taxonomies analysed in the mobile learning research from 2009 to 2018

Based on the research questions that guided this study, the above categories were organized under the following higher dimensions: bibliometrics, research purposes, context, methodology and outcomes. Figure 5 shows the list of main analysed mobile learning categories, grouped in five dimensions.

Figure 5 Taxonomies analysed in the mobile learning research from 2009 to 2018

For each of the thirteen categories, coding was assigned based on the 25 studies included in this research. The next sections of the paper present the fourth phase of the systematic review: guided by the taxonomies described above, a statistical analysis was conducted.

3.2 Bibliometrics

A bibliometric analysis is a method to evaluate scientific research literature by measuring certain indicators (Thelwall, 2008). In particular, it uses quantitative statistics to summarize publication information.

3.2.1 Distribution trend

Erford, Savin-Murphy, and Butler (2010) pointed out that trend analysis can show the periodic discussion taking place in a knowledge discipline. Figure 6 shows the distribution of the research studies selected. It was found that from 2009 to 2018, the number of research studies had significantly increased. This finding is consistent with the conclusions of all the 6 studies discussing this trend (Baran, 2014; Chee et al., 2017; Hwang & Wu, 2014; Krull & Duart, 2017). It can be seen that the growth is exponential and has been higher in recent years.

Figure 6 Distribution trend of mobile learning research from 2009 to 2018

3.2.2 Journal contribution to mobile learning

This study represented a wide range of journals developed and developing mobile learning content. A total of 16 different journals published the 25 selected studies.. The conclusions of the top 6 journals are consistent with those of prior studies (Chee et al., 2017; Crompton & Burke, 2018; J.-L. Hung & Zhang, 2012; Hwang & Tsai, 2011; Hwang & Wu, 2014; Krull & Duart, 2017; Liu et al., 2014). Table 2 depicted the journals contributing the most articles towards mobile learning.

Table 2 Distribution of journals of studies included in this research

Journal	*Frequency*
Computers & Education	5
Journal of Educational Technology & Society	2
Journal of Computer Assisted Learning	2

British Journal of Educational Technology	2
Turkish Online Journal of Educational Technology - TOJET	2
International Journal of Mobile Learning and Organisation	2
The International Review of Research in Open and Distributed	1
Computers in Human Behavior	1
Education and Information Technologies	1
Australasian Journal of Educational Technology	1
Journal of Research on Technology in Education	1
Canadian Journal of Learning and Technology / La revue canadienne de l'apprentissage et de la technologie	1
The Journal of Technology Studies	1
Journal of Computing in Higher Education	1
International Journal of Computer Applications	1
Journal of Educational Computing Research	1
Total	25

3.2.3 Citations

Even though only two studies in the systematic review include citations as the variable to consider (Bhat & Al Saleh, 2015; Wu et al., 2012), citation count is an important indicator for measuring research outputs (Luo, Sun, Erdt, Sesagiri Raamkumar, & Theng, 2018).

With a boost in the number of research publications in the past years, an increasing number of impact indicators have been developed to facilitate the process of research evaluation. The more frequently cited articles are usually those that receive greater recognition by others in related fields. Citation counts, however, have become one of the most widely acknowledged metrics to assess research quality, in spite of some controversial drawbacks (Leydesdorff & Shin, 2011; Thelwall, 2016). Most other recognized indicators, such as the h-index for researchers, the Journal Impact Factor (JIF), and the SCImago Journal Rank (SJR) for journals, are also intrinsically based on citation counts (Luo et al., 2018). Citation counts of the 25 studies were gathered from Google Scholar (as on July 2nd, 2018) and are shown in table 3.

Table 3 Citation studies in google scholar as the record of July 2nd, 2018

Study	Citations	Study	Citati
(Al-Zahrani & Laxman, 2016)	13	(Kaliisa & Picard, 2017)	14
(Alrasheedi & Capretz, 2015)	24	(Krull & Duart, 2017)	3
(Baran, 2014)	193	(Kukulska-Hulme & Viberg, 2018)	271
(Bhat & Al Saleh, 2015)	7	(Liu et al., 2014)	79
(Chee et al., 2017)	12	(Mahdi, 2018)	2
(Cheung & Hew, 2009)	157	(Pimmer et al., 2016)	51
(Crompton & Burke, 2018)	49	(Y.-T. Sung et al., 2016)	206
(Frohberg et al., 2009)	380	(Tingir et al., 2017)	6

(Fu & Hwang, 2018)	2	(Virtanen et al., 2018)	2
(Y.-C. Hsu & Ching, 2015)	25	(Wong & Looi, 2011)	363
(J.-L. Hung & Zhang, 2012)	128	(Wu et al., 2012)	589
(Hwang & Tsai, 2011)	348	(Zheng et al., 2018)	1
(Hwang & Wu, 2014)	121		

Wu et al. (2012) categorized highly cited articles as those with 13 or more cites. Based on this scale, 17 out of the 25 articles included in the study fall into this category. Given their recent publication, the 5 studies from 2018, could be expected to have the potential for a high citation count in the future. To complete the analysis, the first author's h-index was also analysed. The h-index mean for the 25 studies was 11. Figure 7 displays the h-indexes for the first authors of the 25 studies.

Figure 7 First authors' H-index. Web of Science as the record of July 2nd, 2018

3.2.4 Geographical distribution

The country categorization was based on the researcher's affiliation. A total of 9 different countries were represented in the 25 articles included in this study. The citation was included in the analysis to add perspective on the relevance associated with the number of articles. As shown in table 4, representing the continent with which researchers in 8 of the 9 studies were affiliated, Asia is the leading continent in terms of the number of articles published and citations. (K. N. Chee et al., 2017; Crompton & Burke, 2018; H.-C. Hung & Young, 2015; Hwang & Tsai, 2011; Krull & Duart, 2017; Liu et al., 2014; Virtanen et al., 2018). Regarding mobile learning research, Taiwan has become the top country in terms of the number of articles and citations, highlighting the contribution of Hwang, G. J.

Table 4 Mobile learning research from 2009 to 2010: geographical distribution by the number of articles, citations and average publication year

Study	*# Articles*	*Aggregate Citations*	*Average Year*
Asia	10	1,812	2,014
Taiwan	4	1,264	2,013
Singapore	2	520	2,010
China	2	3	2,018
India	1	13	2,013
Malesia	1	12	2,017
North America	6	311	2,015
USA	5	287	2,015
Canada	1	24	2,016
Europe	6	630	2,015
Switzerland	2	431	2,013
Finland	1	2	2,018
Spain	1	3	2,017
Turkey	1	193	2,014
UK	1	1	2,018
Middle East	2	9	2,017
Saudi Arabia	2	9	2,017

Australia	1	14	2,017
Australia	1	14	2,017
Total	25	2,776	2,015

3.3 Research purposes

The research purposes of 8 studies were included in our analysis (Al-Zahrani & Laxman, 2016; alZahir, 2011; Chee et al., 2017; Cheung & Hew, 2009; Crompton & Burke, 2018; Fu & Hwang, 2018; Krull & Duart, 2017; Wu et al., 2012).

The variety of the codes used in the coding scheme is significant. For the purposes of this research, (Krull & Duart, 2017; Wu et al., 2012) the coding scheme was adapted to fit all the 49 different research purposes codes identified into the following five categories:

1. Evaluation of effectiveness, focusing on the investigation of whether mobile devices can improve or enhance student learning;
2. Affective domain, including the identification of factors such as student motivation, beliefs, attitudes, perceptions, and values;
3. Design of systems and tools, emphasizing the development and presentation of solutions;
4. Pedagogical frameworks, comprising studies on the development of learning frameworks and strategies promoting, creating and adapting pedagogical approaches; and
5. Attributes, including affordances, usability, demographics, and trends.

After developing the coding scheme, two coders started to code independently. To ensure their consistency, two strategies were used to solve differences: think pair share and group discussions. Table 5 shows the correlation between the original studies' codes and the coding scheme.

Table 5 Mobile learning research purpose different codes from 2009 to 2010

Category	*Original code and study*
Evaluation of effectiveness	Correlation or Cause-and-effect Analysis (Fu & Hwang, 2018); Evaluate effectiveness (Krull & Duart, 2017); Learning outcomes (Cheung & Hew, 2009); Learning performance (Fu & Hwang, 2018); Outcome (Al-Zahrani & Laxman, 2016); Student achievement (Crompton & Burke, 2018); Effectiveness, Evaluation and Personalization System (J.-L. Hung & Zhang, 2012); Evaluating the effects (Chee et al., 2017); Evaluate effectiveness (Wu et al., 2012);
Affective domain	Acceptance (perception), (Al-Zahrani & Laxman, 2016); Acceptance and Issues (J.-L. Hung & Zhang, 2012); Affective domain (Krull & Duart, 2017); Affective domain (Wu et al., 2012); Attitude, Motivation or Anticipation of effort, (Fu & Hwang, 2018); Collaboration and communication, (Fu & Hwang, 2018); Elicit perceptions of M-Learning, (Chee et al., 2017); Evaluate or explore the factors towards M-Learning (Chee et al., 2017); Factors that influence the use of mobile learning (Crompton & Burke, 2018); Learning behaviour or Engagement (Fu & Hwang, 2018); Level of anxiety (Fu & Hwang, 2018); Opinion of Learner or Learning perception (Fu & Hwang, 2018); Satisfaction or Interest (Fu & Hwang, 2018); Students' perceptions, (Crompton & Burke, 2018); User attitudes (perceptions) (Cheung & Hew, 2009)

Design of systems and tools	Design systems (Krull & Duart, 2017); Designing a mobile system for learning (Chee et al., 2017); Specific mobile learning system or applications (Device/App) (Crompton & Burke, 2018); Design systems (Wu et al., 2012)
Pedagogical frameworks and strategies	Cognitive load (Fu & Hwang, 2018); Develop Theory (Krull & Duart, 2017); Strategies and frameworks (J.-L. Hung & Zhang, 2012); Viability of mobile devices as an assessment too (Cheung & Hew, 2009); Type of pedagogy used in mobile learning (Crompton & Burke, 2018)
Attributes	Evaluate the Influence of Learning Characteristics (Krull & Duart, 2017); Evaluate the Influence of Learning Characteristics (Wu et al., 2012); Explore Potential (Krull & Duart, 2017); Mobile learning case studies (J.-L. Hung & Zhang, 2012); Readiness (usability) and outcome (Al-Zahrani & Laxman, 2016); Self-efficacy, Confidence or Anticipation performance (Fu & Hwang, 2018); Usage profile (Cheung & Hew, 2009); Research Trends (Al-Zahrani & Laxman, 2016)

Based on this classification, Figure 8 shows that the most common research purpose is the evaluation of effectiveness (33%), followed by affective domain (24.5%), affordances, uses and trends (22%), design, systems and tools (12.4%), and finally pedagogical frameworks (8.0%).

Figure 8 Mobile learning research purposes from 2009 to 2010

Although it would be much more interesting to focus this study on a review of the literature on the use of different mobile learning strategies (Hwang, Lai, & Wang, 2015), we unfortunately do not have enough resources to carry out the analysis with the methodology used.

Regarding the research purpose category, our results are consistent with other studies conducted in this type of research (Bhat & Al Saleh, 2015; Boticki, Looi, & Wong, 2011; Frohberg et al., 2009; Y. Hsu & Ching, 2015; Kaliisa & Picard, 2017; Liu et al., 2014; Pimmer et al., 2016; Tingir et al., 2017; Virtanen et al., 2018).

3.4 Demographics and context

In the present study, the demographics and context of the selected 25 studies were analysed in terms of five categories: sample size and range; sample type and educational level; learning environment; learning domain; and device.

3.4.1 Sample size and range

Two subcategories were included in this category, namely, sample size and the period of time analysed. The mean sample size of the studies included in this research is 73.12 publications per study, with a standard deviation of 65.76. The variation over the years is not significant, and the Pearson correlation coefficient p is 0.21. Figure 3 shows the evolution of the sample size across the years.

In relation to the period of time for each article, the mean range of years across articles is 8.88 years per study, with a standard deviation of 3.822. The trend of the variation over the years is not significant. For the correlation coefficient, r =+0.15. Figure 9 shows the evolution of the range of years included in the studies across the years.

Figure 9 Histogram and mean of the number of years analysed in mobile learning research

In terms of original studies, only two studies analysed the sample size in their articles, (Fu & Hwang, 2018; Zheng et al., 2018). Both coded the groups into a small, medium and large sample size (using different ranges) and concluded that the majority of studies adopted a medium sample size.

3.4.2 Sample type and educational levels

The sample type refers to the educational stakeholders comprising the researched target group for mobile learning. Five studies reported results in this field. Table 6 shows the different names for this field and the codes given by each study. For the purpose of this study, the sample type was coded as follows: students, faculty or teachers, and other or non-specified.

Table 6 Sample target names and codes studied in mobile learning from 2009 to 2018

Study	*Category Name*	*Study code*	*Proposed code*
(Fu & Hwang, 2018)	Participants	Non-specified	Other
		Students	Learners
		Teachers	Educator
		Working adults	Other
(Krull & Duart, 2017)	Population groups	Faculty	Educator
		Other	Other
		Students	Learners
(Hwang & Tsai, 2011)	Sample Group	Non-specified	Other
		Students	Learners
		Teachers	Educator
		Working adults	Other
(Chee et al., 2017)	Sample individual	Elementary or Primary Student	Educator
		Elementary or Primary Teacher	Educator
		High School or Secondary Students	Learners
		High School or Secondary Teacher	Educator
		Higher education Instructor	Educator
		Higher Education Student	Learners
(Crompton & Burke, 2018)	Educations levels	Faculty	Educator
		Graduate	Learners
		Undergraduate	Learners

Based on the above codes, the five studies' results were combined. Due to the lack of availability of some original databases, the studies' overlaps could not be adjusted; consequently, the weighted results could not be shown. Table 7 demonstrates the results of the analysis by sample type.

Table 7 Sample type in mobile learning research from 2009 to 2018

Study	*Sample size*	*Learner*	*Educator*	*Other*
(Chee et al., 2017)	144	78%	22%	0%

(Crompton & Burke, 2018)	72	98%	2%	0%
(Fu & Hwang, 2018)	90	91%	4%	5%
(Hwang & Tsai, 2011)	154	76%	4%	20%
(Krull & Duart, 2017)	233	78%	10%	12%

It was found that the vast majority of studies were aimed at students (above 76%). Students were the most often researched group members for mobile learning studies. With one exception (Chee et al., 2017), few studies targeted faculty or teachers (less than 10%).

With regard to educational levels, the studies were grouped into four major categories: higher education, high or secondary, elementary, and other or not specified. A total of 8 studies analysed educational levels. Table 8 shows the different names for this field and the codes given by each study.

Table 8 Names and Codes of the Educational level studied in mobile learning from 2009 to 2018

Study	*Category Name*	*Study code*	*Proposed code*
(Wu et al., 2012)	Education Contexts	Elementary	Elementary
		Higher education	Higher education
		High or secondary	High or secondary
(Tingir et al., 2017)	Grade Level	Elementary	Elementary
		High	High or secondary
		Middle	Elementary
(Liu et al., 2014)	Grade-level distribution (k-12)	Elementary	Elementary
		High school	High or secondary
		Middle school	Elementary
(Mahdi, 2018)	Level	Elementary	Elementary
		High school	High or secondary
		University	Higher education
(Fu & Hwang, 2018)	Participants	Elementary students	Elementary
		High school students	High or secondary
		Higher education	Higher education
(Y.-T. Sung et al., 2016)	Participants	Adults	Other/Not specific
		College	Higher education
		Elementary school	Elementary
		High school	High or secondary
		Kindergarten	Elementary
		Middle school	Elementary
		Mixed	Other/Not specific
(Hwang & Tsai, 2011)	Sample Group	Elementary students	Elementary
		High school students	High or secondary
		Higher education	Higher education
(Zheng et al., 2018)	Sample groups	Elementary school	Elementary
		High school	High or secondary
		Higher education	Higher education
(Chee et al., 2017)	Sample Institution	Elementary or primary	Elementary
		High or secondary	High or secondary

Higher education	Higher education
Not Specific	Other/Not specific
Working adult	Other/Not specific

Based on the above categories, the results of the nine studies covering educational level are shown in table 9. For the same reasons described previously, the weighted results cannot be shown. However, we could reasonably conclude that higher education is the level where more research has been conducted and that high school or secondary schools comprise the levels with the lowest number of studies. This fact is confirmed in the two studies focusing on K through 12 students and in which the focus on elementary school students is significantly higher than that on high school or secondary school students. "There is tremendous room for research to be carried out for other samples such as secondary or high school and working adults" (Chee et al., 2017, p. 11).

Table 9 Distribution of educational levels in mobile learning from 2009 to 2018

Study	Sample size	Elementary	High or secondary	Higher education	Other/ Non-specified
(Chee et al., 2017)	144	21%	6%	36%	18%
(Fu & Hwang, 2018)	90	27%	17%	55%	0%
(Hwang & Tsai, 2011)	154	27%	11%	62%	0%
(Liu et al., 2014)	63	69%	21%	*	10%
(Mahdi, 2018)	16	6%	25%	69%	0%
(Y.-T. Sung et al., 2016)	110	15%	9%	38%	4%
(Tingir et al., 2017)	14	71%	29%	*	0%
(Wu et al., 2012)	164	22%	4%	74%	0%
(Zheng et al., 2018)	34	65%	6%	29%	0%

*Studies focused on k12 students.

3.4.3 Learning environment

The portability of mobile devices enables the use of mobile learning in authentic settings outside the classroom and the engagement in content learning within a specific context. Outside classroom education has been associated with informal learning; however, Chee et al. (2017) found that boundaries between formal and informal learning spaces were blurred when students had access to mobile technologies. "Notions of formal and informal learning are, however, very vague and need to be clarified in this context" (Pimmer et al., 2016, p. 9). Moreover, the debate is moving towards physical and digital or virtual contexts (Wong & Looi, 2011).

Ten studies analysed the learning environments or contexts, providing different category names for which codes were assigned. The categories were grouped into three codes: formal, informal and both or non-specified. Table 10 displays the different category names and the codes used in the studies analysed.

Table 10 Learning environment category names and codes in mobile learning research

Study	*Category Name*	*Study code*	*Proposed code*
(Bhat & Al Saleh, 2015)	Educational Contexts	Non-Informal	Non-Informal
		Informal	Informal
		Formal	Formal
(Chee et al., 2017)	Educational Contexts	Formal and Informal	Formal and Informal
		Informal Learning	Informal Learning
		Formal Learning	Formal Learning
(Crompton & Burke, 2018)	Educational Contexts	Both	Both
		Informal	Informal
		Formal	Formal
(Frohberg et al., 2009)	Context	Independent Context	Independent Context
		Physical context and socializing context	Physical context and socializing context
		Formalizing context	Formalizing context
(Fu & Hwang, 2018)	Learning environment	Others and non-specified	Others and non-specified
		School Campus; Museum library, ecological area and science park	School Campus; Museum library, ecological area and science park
		Classroom or laboratory	Classroom or laboratory
(Hwang & Wu, 2014)	Contexts	Both indoor and outdoor	Both indoor and outdoor
		Outdoor	Outdoor
		Indoor	Indoor
(Krull & Duart, 2017)	Research Settings	Not Specific	Not Specific
		Out of Class; Field	Out of Class; Field
		In Class	In Class
(Y.-T. Sung et al., 2016)	Implementation setting	Not mentioned and Unrestricted	Not mentioned and Unrestricted
		Informal settings	Informal settings
		Formal settings	Formal settings
(Wu et al., 2012)	Educational Contexts	Non-formal; N/A	Non-formal; N/A
		Informal	Informal
		Formal	Formal
(Zheng et al., 2018)	Intervention settings	Mixed	Mixed
		Informal settings	Informal settings
		Formal settings	Formal settings

Based on the above codes, the ten studies' results were combined. Due to the lack of availability of some original databases, there were overlaps that could not be adjusted; consequently, the weighted results could not be shown. However, a comparison can be done with each research study's results. A total of five studies showed that most research was carried out in hybrid environments. There is a significant difference between older studies, where the most common environment was formal, and newer studies, in which

the most used environment was an informal one. Table 11 shows the distribution of the studies by learning environment, and table 12 shows the distribution per years.

Table 11 Distribution of studies by learning environment in mobile learning research from 2009 to 2018

Study	*Sample size*	*Formal*	*Informal*	*Hybrids/A*
(Bhat & Al Saleh, 2015)	13	17%	16%	67%
(Chee et al., 2017)	144	8%	11%	81%
(Crompton & Burke, 2018)	72	54%	36%	8%
(Frohberg et al., 2009)	102	27%	42%	32%
(Fu & Hwang, 2018)	90	30%	45%	25%
(Hwang & Wu, 2014)	214	39%	18%	43%
(Krull & Duart, 2017)	233	16%	24%	60%
(Y.-T. Sung et al., 2016)	110	56%	19%	25%
(Wu et al., 2012)	164	66%	7%	27%
(Zheng et al., 2018)	34	21%	50%	29%
Mean	118	33%	27%	40%

Table 12 Distribution of studies by formal and informal environment in mobile learning research across the recent years

Year	*Study*	*Formal*	*Informal*
2009	(Frohberg et al., 2009)		1
2012	(Wu et al., 2012)	1	
2014	(Hwang & Wu, 2014)	1	
2015	(Bhat & Al Saleh, 2015)	1	
2016	(Y.-T. Sung et al., 2016)	1	
2017	(Chee et al., 2017)		1
2018	(Crompton & Burke, 2018)	1	

3.4.4 Learning domain

Almost half of the studies (11) included in this research analysed the impact of the learning domain. All the phrases used to refer to this category included the word domain or discipline and included the following: subject domain, learning domain, subject matter domain, learning subjects, academic disciplines, subject area, disciplines, and courses. The learning contents varied significantly between the studies. More than 50 different codes were identified and grouped into the following seven categories: engineering (including computers), language and art, mathematics, science, social science, and others and no specified (Chee et al., 2017; Hwang & Tsai, 2011).

The results shown in table 13 demonstrate that science and social science are the two domains most studied in the mobile learning field. Mathematics is the academic discipline less frequently examined in mobile learning studies. However, the results are limited to the group sample of each study. Some studies' participants were limited to individuals

with a higher education (Krull & Duart, 2017; Pimmer et al., 2016; Virtanen et al., 2018), and others were focused on K through 12 participants (Cheung & Hew, 2009).

Table 13 Distribution of learning domains groups for mobile learning research from 2010 to 2018

Study	*Engineering*	*Language & Art*	*Mathematics*	*Science*	*Social science*	*Other*
(Hwang & Tsai, 2011)	14%	16%	4%	19%	7%	40%
(Hwang & Wu, 2014)	9%	18%	3%	9%	22%	40%
(Krull & Duart, 2017)	0%	0%	0%	15%	54%	30%
(Y.-T. Sung et al., 2016)	12%	35%	10%	29%	9%	5%
(Tingir et al., 2017)	0%	60%	20%	20%	0%	0%
(Wu et al., 2012)	0%	0%	0%	65%	35%	0%
(Zheng et al., 2018)	0%	0%	0%	76%	24%	0%
(Baran, 2014)	0%	12%	9%	14%	3%	65%
(Chee et al., 2017)	4%	13%	3%	12%	8%	60%
(Crompton & Burke, 2018)	7%	21%	0%	6%	34%	31%
(Fu & Hwang, 2018)	15%	16%	3%	25%	22%	19%
Mean	**6%**	**17%**	**5%**	**26%**	**20%**	**26%**

3.4.5 Devices

The domain category devices was investigated by 14 studies. Combining all studies, coding was assigned to as many as 15 different devices, namely, mobile phones, smartphones, tablets, laptops, PDAs, handheld PCs, iPads, handheld devices, pocket PCs, notebooks, iPods, MP3 players, eBook readers, wearables devices, and game consoles. Coding and evaluating devices are challenging and present several limitations. On the one hand, owing to the rapid advancement of mobile technologies, the types of mobile devices adopted by researchers and educators have significantly changed in the past decade (Hwang & Wu, 2014). Researchers found that the latest technology provides better portability, interactivity, and autonomy to meet the needs of mobile learning. Consequently, research findings are likely to change with ongoing technological development. On the other hand, diverse technology devices are applied simultaneously in education, as learners start to use their own mobile devices for learning. Mobile learning devices are losing ground to the emerging platforms where learners can retrieve the same learning resources with different types of devices. Multiple device usage and BYOD (Bring Your Own Device) strategies are widely integrated into educational environments. According to Horizon report 2017, in the US, each student has on average 3.2 devices (Freeman, Becker, Cummins, & Davis, 2017). BYOD goes beyond access to devices, as students are no longer limited to institutional systems but increasingly have their own internet access and make use of their own services. Devices are important, but the associated systems and networks are equally significant (Traxler, 2016).

Some recent studies proved that the non-significant differences in device type suggest that the device effect on student achievement does not exist (Tingir et al., 2017). Consequently, this study could not answer the research question related to which mobile devices are more used.

3.3 Methodologies

3.3.1 Research methods

This study found 5 articles where methods were grouped into three main categories, which were coded as quantitative, qualitative and mixed (Chee et al., 2017; Fu & Hwang, 2018; Kaliisa & Picard, 2017; Krull & Duart, 2017; Zheng et al., 2018). Five articles included in this investigation performed meta-analysis research that focused on the use of quantitative methodologies or experimental or quasi-experimental research (Alrasheedi & Capretz, 2015; Mahdi, 2018; H.-Y. Sung, Hwang, & Chang, 2016; Tingir et al., 2017; Wu et al., 2012). In social science research, often, strategies and methodologies are difficult to differentiate. Guba 1981 introduced different strategies to deal with fundamental research criteria (credibility, transferability, dependability and confirmability). This study highlighted the importance of defining the appropriate strategy, where different methodologies, namely, quantitative and qualitative, could be applied .(Rikala, 2015) adopted and extended Guba's strategies, including triangulation, peer debriefing, research context descriptions, interactive comparations, and reflective journals. Based on the above, for our study, the research methods were coded into three groups: quantitative; qualitative and mixed. Table 14 shows the research methodologies results.

Table 14 Research methodologies used in mobile learning research from 2009 to 2018

Study	*Sample size*	*Quantitative*	*Qualitative*	*Mixed*	*Not specific*
(Chee et al., 2017)	144	48%	16%	19%	18%
(Fu & Hwang, 2018)	90	36%	12%	37%	16%
(Kaliisa & Picard, 2017)	31	19%	10%	42%	29%
(Krull & Duart, 2017)	233	43%	46%	11%	N/A
(Zheng et al., 2018)	34	56%	0%	44%	N/A

With the exception of (Krull & Duart, 2017), the quantitative approach is the most employed research methodology for mobile learning studies, followed by mixed methods. Fu and Hwang (2018) analysed this tendency, concluding that quantitative analysis and mixed analysis increased enormously in the last 10 years, as researchers emphasized the empirical experience in both experimental environments and real scenarios.

3.3.2 Data collection methods

A total of 7 studies analysed the different data collection methods applied in mobile learning research (Cheung & Hew, 2009; Crompton & Burke, 2018; Kaliisa & Picard, 2017; Krull & Duart, 2017; Virtanen et al., 2018; Wu et al., 2012; Zheng et al., 2018). As many as 21 different collection methods were identified: audio recording, classroom observation, content analysis, discussions, document review, feedback, field notes, focus groups, interviews, observations, observations via video, peer teaching, process data, product data, questionnaires, surveys, systematic reviews of the literature, teacher blogs,

tests or quizzes, weekly journals and written materials. These collection methods were grouped into five categories adapted from Cheung and Hew (2009) and Krull and Duart (2017). The codes included the following: questionnaires and surveys, interviews and focus groups, content analysis, observation and mixed methods. Table 15 depicts the data collection methods most commonly used in mobile learning research.

Table 15 Research methodologies used in mobile learning research from 2009 to 2018

Study	*Sample size*	*Questionnaire*	*Interview*	*Content analysis*	*Observation*	*mixed methods*
(Cheung & Hew, 2009)	44	54%	18%	21%	7%	0%
(Crompton & Burke, 2018)	72	54%	15%	3%	0%	28%
(Kaliisa & Picard, 2017)	31	54%	36%	6%	4%	0%
(Krull & Duart, 2017)	233	61%	18%	18%	3%	0%
(Virtanen et al., 2018)	7	36%	36%	27%	0%	0%
(Wu et al., 2012)	164	39%	4%	15%	5%	37%

The most commonly used data collection method are questionnaires and surveys, observation is the category less used. Mixed methods category' results are limited by the studies not including this category. However, as per other results analysed in this study using mixed collection methods is a current trend: "The studies examined in this review used varied methodologies, with a majority being case studies or mixed method" (Baran, 2014, p. 7); "All of studies adopted mixed data sources to collect data" (Zheng et al., 2018, p. 12); "Of the articles reviewed, 79% represented investigations exploratory in nature using various data sources" (Liu et al., 2014, p. 6).

3.4 Outcome

Based on the studies analysed, there are different approaches to measure outcomes. Some studies referred to learning outcomes as the measure to determine if the use of mobile learning can improve or enhance the students' learning knowledge. In most cases, the authors labelled these outcomes as follows: positive, negative, and neutral. This research topic was investigated by 10 studies (Chee et al., 2017; Crompton & Burke, 2018; Fu & Hwang, 2018; Liu et al., 2014; Mahdi, 2018; Pimmer et al., 2016; Y.-T. Sung et al., 2016; Virtanen et al., 2018; Wu et al., 2012; Zheng et al., 2018). Table 16 shows the results of the five studies reporting quantified outcome results. The other five studies reported overall positive outcomes (Cheung & Hew, 2009; Pimmer et al., 2016; Y.-T. Sung et al., 2016; Virtanen et al., 2018).

Table 16 Mobile learning research outcomes from 2009 to 2018

Study	*Sample size*	*Positive*	*Negative*	*Neutral*
(Chee et al., 2017)	144	53%	3%	44%
(Crompton & Burke, 2018)	72	70%	4%	26%
(Hwang & Wu, 2014)	214	32%	7%	61%
(Liu et al., 2014)l	63	75%	N/A	25%
(Wu et al., 2012)	164	86%	1%	13%

A second approach included focusing on the affective domain (Cheung & Hew, 2009; Pimmer et al., 2016). The results showed that overall, students are engaged and like using handheld devices. Finally, to analyse mobile learning outcomes, on top of learning knowledge and satisfaction, a third approach added a new dimension, namely, usage. Usage measures the frequency, intensity and/or quality of the learners' engagement. According to Pimmer et al. (2016), this last aspect is an important complementary indicator because mobile learning activities that are highly rated but rarely used by learners would have only limited effects. Three of the studies included in this investigation (Frohberg et al., 2009; Pimmer et al., 2016; Y.-T. Sung et al., 2016) highlighted the importance of underpinning mobile learning designs to pedagogical strategies, curriculum and to the further assessment of skills in order to ensure accurate outcomes' measurement.

4. Discussion

The study reveals that in the analysis of mobile learning, there is a vast literature, whose results are significantly consistent in their main aspects. The findings revealed that the number of articles published has increased over the last years, with significant contributions from Asia, and that most studies feature positive outcomes. The main focus of the studies has been on learning effectiveness; the majority of the target sample are students, and the environment is a hybrid one, with a tendency to being informal. Moreover, mixed research methodologies are the common trend. The results also evidenced and recognized the lack of current research focused on the development of theoretical frameworks and models for the sustainable adoption of mobile learning.

One of the main limitations of this study is that due to the breadth and complexity of the research on this subject, this study focuses on previous reviews and not on original studies.

The findings suggest that there is a need for standardization and categorization to build solid foundations for mobile learning research.

This study analysed the current status of mobile learning research between 2008 and 2018 and proposes a new taxonomy based on 13 taxonomies, which are grouped into five domains: bibliometric statistics; research purposes; demographics and context; methodologies; and outcomes.

This new taxonomy contributes to a deeper understanding of mobile learning: this has implications for academics. This taxonomy can guide future research efforts, is expected to optimize the research process in the field of mobile learning and can contribute to moving towards sustainable and effective adoption models. Having implications for educational stakeholders interested in mobile learning, the taxonomy proposed provides a quick and comprehensive overview.

The directions for further research in mobile learning may include the promising area of developing theoretical frameworks and models for sustainable mobile learning adoption and the development of efficient procedures and tools to ensure accurate outcomes' measurement.

5.Conclusions

This study analysed 25 previous literature review-based studies on mobile learning in education from 2009 to 2018 and provides a more comprehensive analysis and guidance in the field. The aim of this study was to identify the current status of mobile learning research and to consolidate the bases for its adoption and sustainable development.

One of the major contributions of this study has been the proposal of a taxonomy and the identification of the need to standardize and categorize the main aspects of mobile learning.

Combining the 25 studies, 99 categories were analysed and grouped into 13 categories. Those categories were assembled and organized under five higher dimensions: bibliometrics, research purposes, demographics and context, methodology, and outcomes.

The results of the state of mobile learning research for each specific research question are as follows: RQ1: Why is mobile learning relevant?

The review revealed that the number of articles published has significantly increased over the last ten years. The top 15 journals account for 47.2% of mobile learning literature. Both the number of articles and the number of authors' citations are high. Asia is the continent with more contributions to mobile learning research, and Taiwan is the most dominant country.

RQ2: What has been investigated? What are the research purposes?

Most studies of mobile learning have focused on effectiveness, affective domain and affordances. There is a noticeable lack of emphasis on frameworks and strategies. Therefore, there is a need to develop solid, simple and effective frameworks for the adoption and sustainable use of mobile learning. This is a suggested area for future research in mobile learning.

RQ3: Who and where is the target? What are the demographics and the context?

Students are the most studied target. Most mobile learning studies used a sample from higher education; there is a significant need for conducting secondary education research. Most research was conducted in hybrid environments, and there is a tendency in the research towards studying informal environments. However, there is a need to investigate and evolve environment categorization into broader concepts connected with virtual environments. In relation to the learning domain, the spectrum is too wide to make conclusions. Similarly, the variety of mobile learning devices are constantly growing: consequently, research findings are likely to change with ongoing technological development. In addition, BYOD (Bring Your Own Device) strategies and multiple device usage are widely integrated into educational environments. New tendencies showed the relevance of mobile learning software.

RQ4: How has the research has been conducted? What methodology has been used?

There is a clear trend to use mixed methodologies and a wide variety of data collection methodologies.

RQ5: What are the main outcomes in the studies of mobile learning?

The studies revealed that the use of mobile learning can improve or enhance the students' learning knowledge. The results also showed that overall, students are engaged and like using handheld devices. There is a need to develop efficient procedures and tools to ensure the accurate outcomes' measurement. This area has been identified as a future direction for research in the field of mobile learning. This area has been identified as a future direction for research in the field of mobile learning. Figure10 shows a model that orchestrates and summarizes the current research in mobile learning.

Figure 10 A conceptual model for mobile learning research

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Figures

Figure 1 Diagram of the literature search process

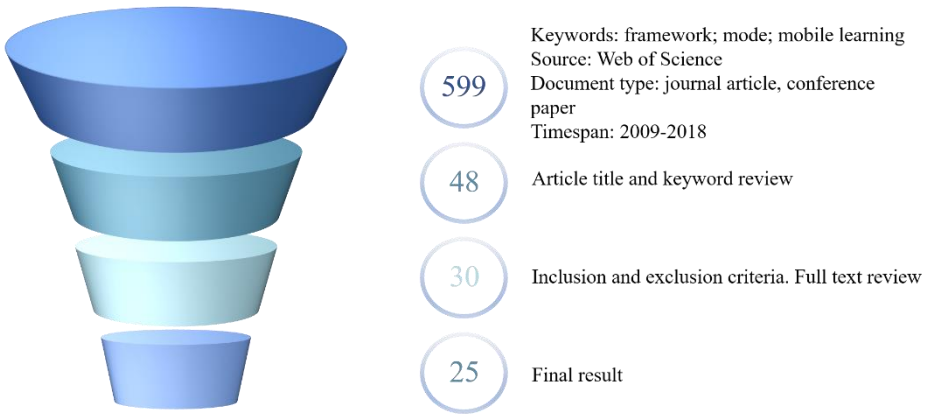

Figure 2 Distribution of the number of categories analysed in the mobile learning research from 2009 to 2018

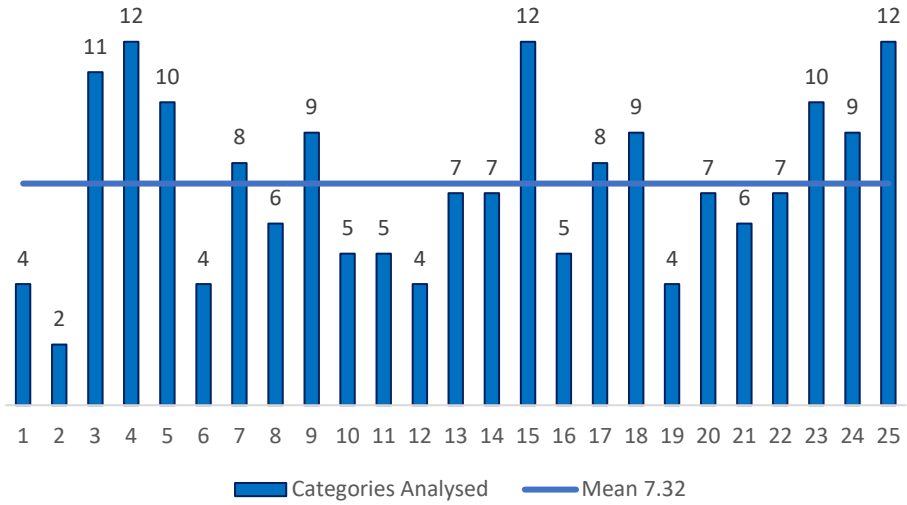

Figure 3 Distribution of the sample size in mobile learning research from 2009 to 2018

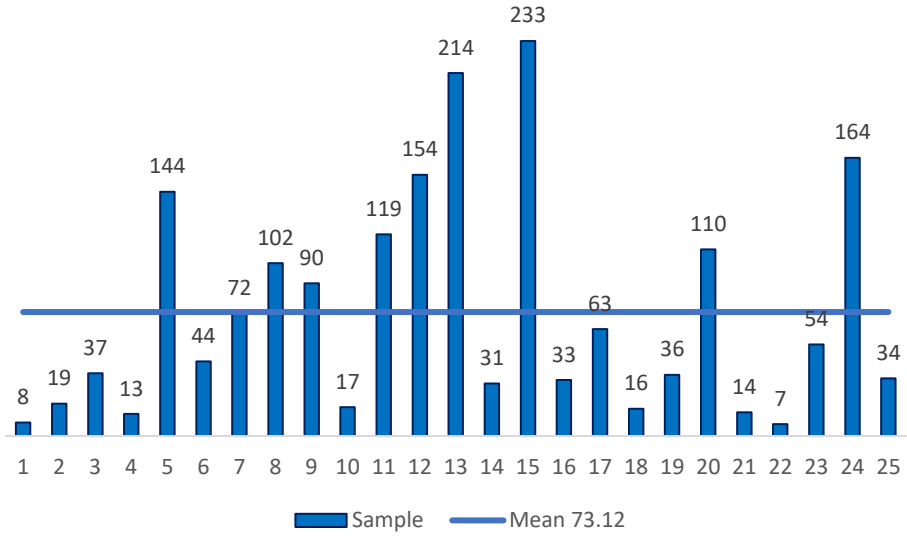

Figure 4 Distribution of taxonomies analysed in the mobile learning research from 2009 to 2018

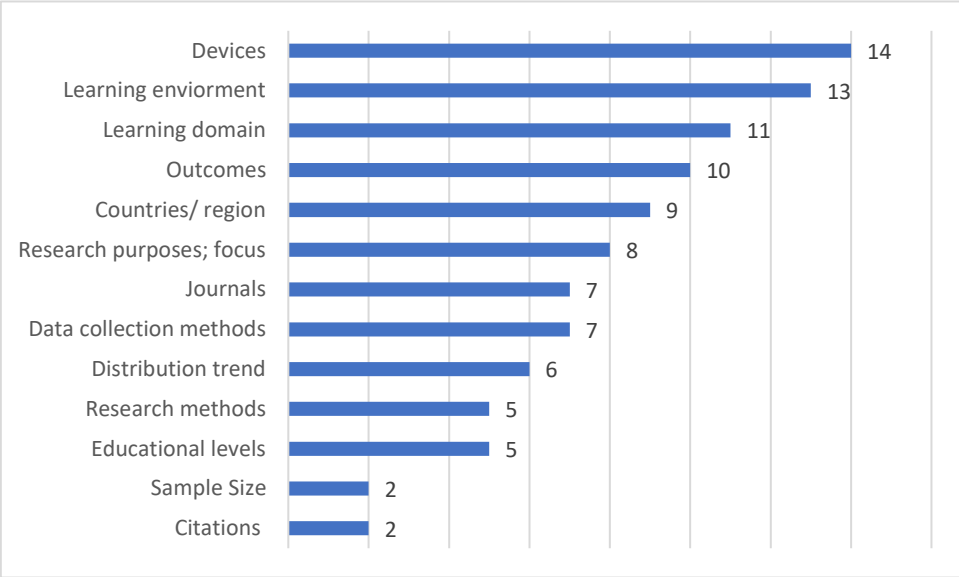

Figure 5 Taxonomies analysed in the mobile learning research from 2009 to 2018

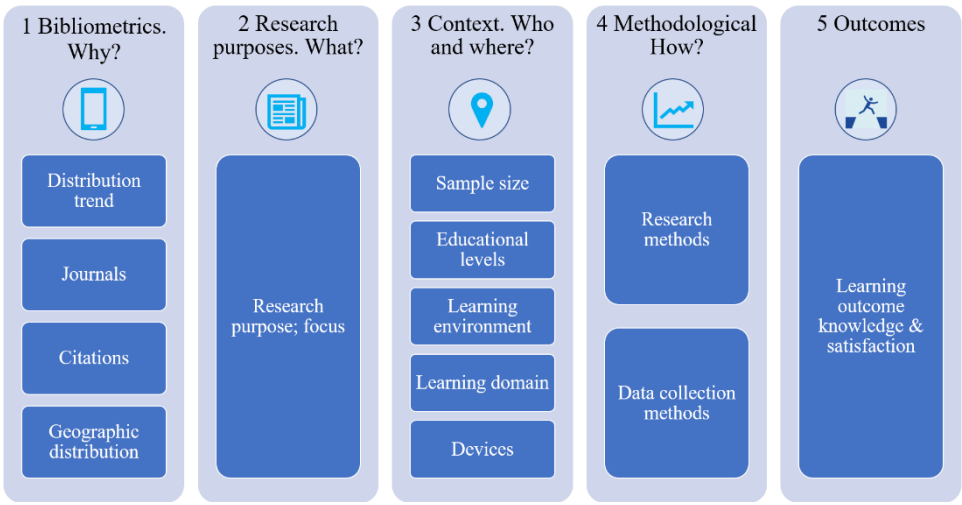

Figure 6 Distribution trend of mobile learning research from 2009 to 2018

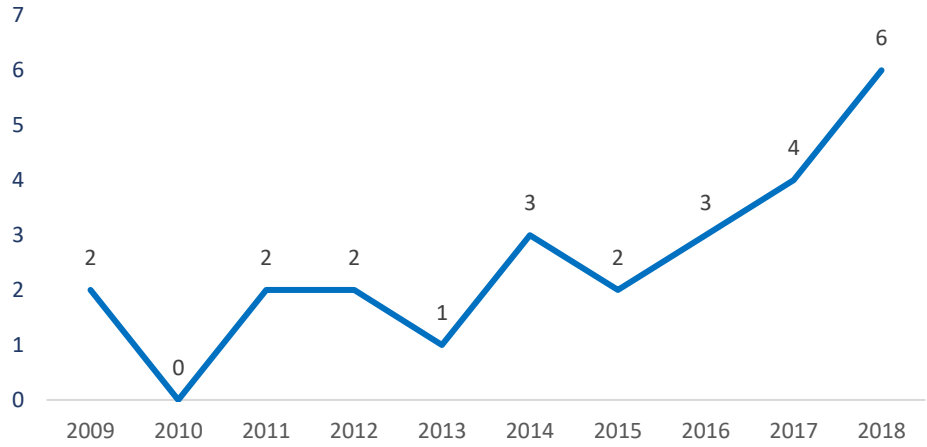

Figure 7 First authors' H-index. Web of Science as the record of July 2nd, 2018

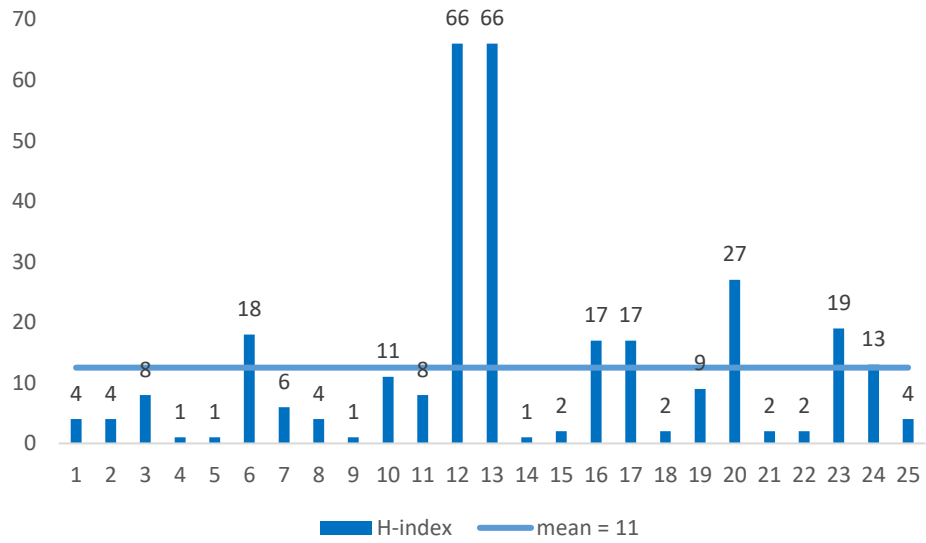

Figure 8 Mobile learning research purposes from 2009 to 2010

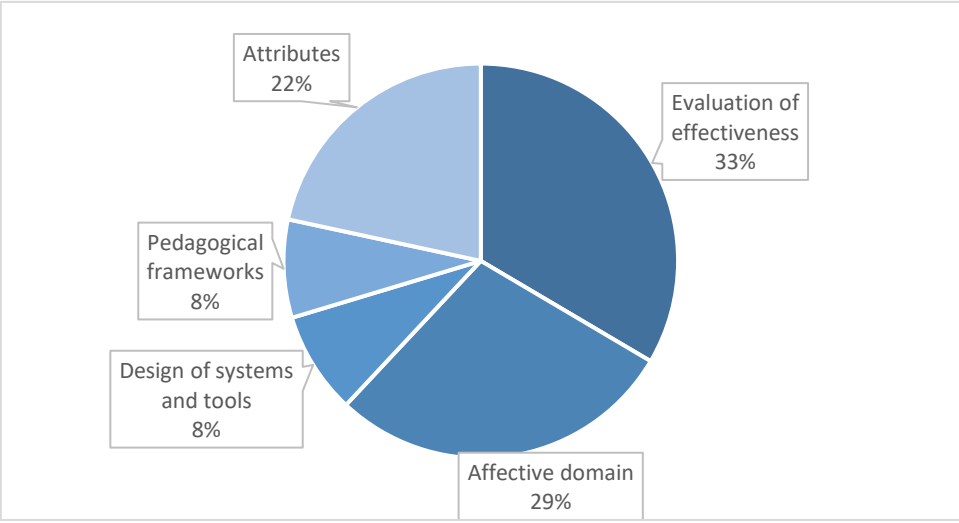

Figure 9 Histogram and mean of the number of years analysed in mobile learning research

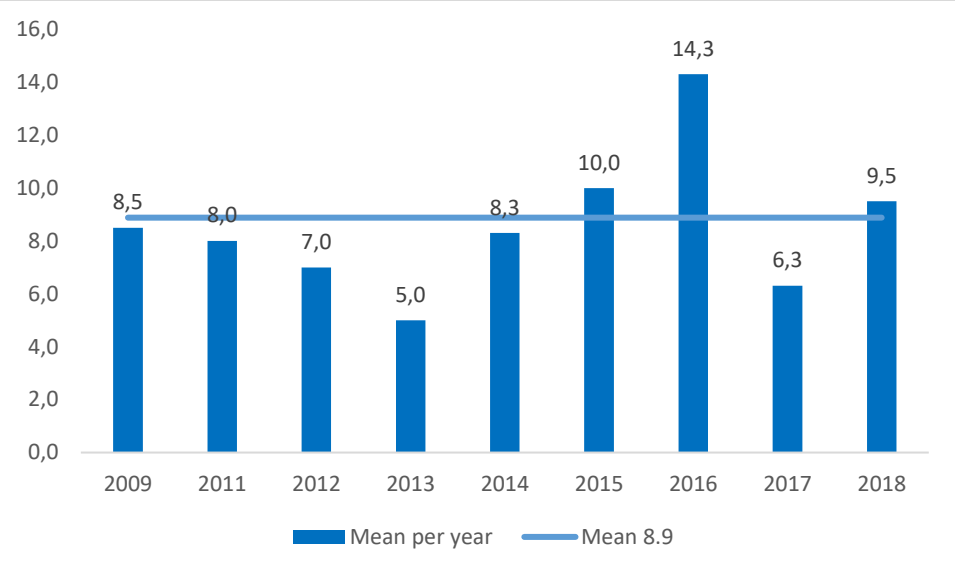

Figure 10 A conceptual model for mobile learning research