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Original Article

Journal of Advances in Medical Education & Professionalism

The educational effects of mobile learning on students of medical sciences: A systematic review in experimental studies

HAMID REZA KOOHESTANI[1], SEYED KAMRAN SOLTANI ARABSHAHI[1*], LADAN FATA[1], FAZLOLLAH AHMADI[2]

[1]Department of Medical Education, School of Medicine, Iran University of Medical Sciences, Tehran, Iran; [2]Nursing Department, Faculty of Medical Sciences, Tarbiat Modares University, Tehran, Iran

Abstract

Introduction: The demand for mobile learning in the medical sciences educational program is increasing. The present review study gathers evidence highlighted by the experimental studies on the educational effects of mobile learning for medical sciences students.
Methods: The study was carried out as a systematic literature search published from 2007 to July 2017 in the databases PubMed/Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Knowledge (Thomson Reuters), Educational Resources and Information Center (ERIC), EMBASE (Elsevier), Cochrane library, PsycINFO and Google Scholar. To examine quality of the articles, a tool validated by the BEME Review was employed.
Results: Totally, 21 papers entered the study. Three main themes emerged from the content of papers: (1) improvement in student clinical competency and confidence, (2) acquisition and enhancing of students' theoretical knowledge, and (3) students' positive attitudes to and perception of mobile learning. Level 2B of Kirkpatrick hierarchy had been examined by all the papers and seven of them had reported two or more outcome levels, but level 4 was not reported in the papers.
Conclusion: Our review showed that the students of medical sciences had positive response and attitudes to mobile learning. Moreover, implementation of mobile learning in medical sciences program might lead to valuable educational benefits and improve clinical competence and confidence along with theoretical knowledge, attitudes, and perception of mobile learning. The results indicated that mobile learning strategy in medical education can positively affect learning in all three domains of Bloom's Taxonomy.

Keywords: Mobile applications, Smartphone, Learning, Education, Health occupations, Students

**Corresponding author:*
Seyed Kamran Soltani Arabshahi,
Department of Medical Education, School of Medicine, Iran University of Medical Sciences, Tehran, Iran
Tel/Fax: +98-21-88622607
Email: soltarab.43@tak.iums.ac.ir

Please cite this paper as:
Koohestani HR, Soltani Arabshahi SK, Fata L, Ahmadi F. The educational effects of mobile learning on students of medical sciences: A systematic review in experimental studies. J Adv Med Educ Prof. 2018;6(2):58-69

Received: 18 November 2017
Accepted: 22 January 2018

Introduction

The term "mobile learning" refers to any type of learning using mobile devices through which flexible learning opportunities are created along with higher mobility –i.e. any time and any place. The affordable and easy access to mobile devices in everyday social and work life of learners brings an interesting chance to upgrade teaching and learning (1). Fast technological advances have resulted in the rebirth of personal computers (PC) in smartphone and tablets forms (2). Currently, we can enjoy a highly mobile environment so that mobile technology is now a pivotal element of the modern life (3). Mobile devices including smart phones with a variety of functionalities and convergence of technologies have led to creation of an exciting unprecedented opportunities for teaching and learning on the move (1). The devices are capable of offering rich and interactive multimedia learning materials for educational ends (4). A key step to this end is the access to resources and this access is efficiently and easily provided by mobile technology (5). A wide range of combined functions such as instant messaging and logs that is provided by social networks can be utilized to enhance personalized learning opportunities. Along with the Internet connectivity, smart phones can play podcasts of lectures and tutorials for students at different places and times (1).

The recent years have been featured with expansion of mobile technology in educational fields and its acceptance by the students (6). Today, almost all students have a mobile phone with capability to search for information (3). Mobile technologies (e.g. handheld and wearable) are featured with the capacity to improve learning activities throughout medicine programs from basic medical undergraduate education to residency and beyond (7). Medical students and residents have already shifted to mobile technologies including mobile phones and small laptops for cultural purposes and a notably deep learning in a very rapid way (8). Smartphones have become an integral part of social life, being widely accepted in a variety of professions (9). They are even used for educational objectives in medicine programs in the form of information source and reference, a guide in rounding, improving access to pertinent information, enhancement of learning in the clinical practicum, and improvement of problem-based learning (10-13). Mobile phones are accepted as a reliable tool to find answers to clinical question so that it is possible to revolutionize medical education and practice and support the transition from novice to expert using mobile technology (14). Educational courses designed based on smart phones facilitate a self-directed learning environment that gives the users the opportunity to have frequent access to information and practice beyond physical and time limitations. It is very common for the students to feel a pressure during the theoretical or practical courses in lab or hospital. Still, smartphone-based education offers opportunity to enjoy a non-judgmental learning environment where the students can practice as much as they would like without the fear of making errors (15).

There are several experimental studies on the effects of mobile learning intervention in medical science education. For example, Yoo, et al. (2015) carried out a study on the effectiveness of using a mobile application for the purpose of cardiopulmonary assessment education through comparing the educational results with those using a high-fidelity human patient simulator. The finding indicated that mobile applications can be used as an educational tool with equal effectiveness to a high-fidelity human-patient simulator to memorize and teach cardiopulmonary assessment skills (3). Davis, et al. (2012) carried out a study to examine medical students' chest tube insertion performance when viewing short, just-in-time mobile learning videos. The results indicated that the participants who watched the video scored better in the skills checklist comparing with the control group (16). Tews, et al. (2012) conducted a study to evaluate medical students' case presentation performance and perception after watching short, just-in-time mobile learning videos using the iPod touch before dealing with the patients. The result confirmed a statistically significant improvement in presentation after watching the video for the first time. Moreover, a reliable survey showed that the videos were useful teaching tools with which the subjects felt more confident in presentations (17).

Still, there is a need of a systematic evaluation of the outcome of mobile learning interventions for medical sciences education. The present review study focuses on the educational effects of mobile learning on the students in medicine programs. The necessity of this work lies in the fact that, comparing with other electronic learning methods, mobile learning is a relatively untapped field of development and a deep and systematic examination of the results of mobile learning in medical sciences education can improve our insights into the subject under consideration. There are several studies on the effects of employing mobile learning in different countries and different levels of undergraduate and post-graduate programs. However, there is no review study for a systematic evaluation of the results of employing mobile learning intervention for the students of medical sciences. So the present study was carried out to synthesize the findings based on the experimental works and offers a deeper insight into the outcome of mobile learning in medical sciences education.

Methods

Framing the question

The present systematic review is aimed at addressing the following questions:

What are the top methodologies, research types, and countries in mobile learning studies in medical sciences education?

Which educational interventions with mobile technology are currently being used by the students of medical sciences?

What are the educational outcomes of mobile-based learning in medical sciences education?

Sources of papers, search strategies and selection process

Information sources

The articles published from 2007 to July 2017 were searched in the databases PubMed/Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Knowledge (Thomson Reuters), Educational Resources and Information Center (ERIC), EMBASE (Elsevier), Cochrane library, PsycINFO and Google Scholar.

Search strategy for identification of studies

The search strategy was discussed with a research librarian employed by the administering institute. Both electronic searchers included free text and thesaurus terms using truncation and proper Boolean operators were employed to locate all the pertinent articles. The search terms were 'mobile learning', 'medical science education', 'mobile learning and medical science education', 'smartphone* OR smart-phone* OR mobile* OR cellphone or cellular phone AND Learning', 'm-learning OR mobile learning'. These terms are supposed to be the most common terms in mobile learning searches. In addition, the search words were adapted to each database. Table 1 represents an instance of the search strategy in PubMed.

Inclusion/exclusion criteria

Data management and study selection

All the databases were searched by one reviewer and Endnote X5 was used for data management. The articles were imported into Endnote X5 to remove the duplicate data before importing the data into Excel. The imported data were the authors, title, journal and year. The titles and abstracts were screened by two independent researchers to determine the potentially relevant

Table 1: Proposed search string for PubMed

Search string	
1	Mobile learning OR mlearning OR m-learning
2	Students OR medical students OR nursing students OR dental students OR dentistry students OR pharmacy students OR health students OR allied health students OR allied medical students OR health professional student OR medical sciences students
3	1 and 2
4	Mobile* OR smartphone* OR smart-phone* OR cellphone* OR cell-phone* OR cellular phone OR mobile phone OR mobile devices OR mobile applications OR mobile app OR smart mobile
5	Learning OR education OR teaching OR instruction OR training
6	2,4 and 5

Table 2: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Types of studies	-Papers published in peer-reviewed journal categorized as high quality literature -Study designs: randomized controlled trials or quasi-experimental designs -Comparison study or a survey study with no comparison group	-Conference papers, book chapters or theses -Non-experimental studies
Focus	Studies on the educational effects of mobile learning in the students of medical sciences	Topics other than medical sciences education such as health and medical services research
Types of outcome measures	Outcomes assessed as self-reported through registries or reported by an educator	-
Publication type	Available in Farsi and English (full text) to facilitate analyses	Full text in either Farsi or English is not available
Setting	Regardless of the country where the study is carried out and types of educational setting (e.g. University, laboratory, medical ward, and community)	-
Population	Undergraduate or postgraduate medical sciences students	Covered professional education or learners not medical sciences students
Time period	Published between 2007 and 2017, which is the period with the highest growth in the use of E-learning	Before and after the inclusion period

articles. The results were recorded in an Excel spread sheet with columns for included, excluded, or unsure papers. The full-texts of the included and unsure articles were secured and eligibility of them was examined based on inclusion criteria. The outcomes were recorded in columns 'inclusion,' 'exclusion,' and 'reason for exclusion.' Any disagreement between the researchers was solved through consensus and a third reviewer if needed (Table 2).

The flowchart illustrated in Figure 1 shows inclusion and exclusion process in the four phases of 'identification,' 'screening,' 'eligibility,' and 'inclusion'(18). The output of the first phase was 1098 articles found in the eight databases. Additionally, an extra 11 references were found through hand searching of the reference lists. Throughout the first step of the "screening" phase, 239 duplicate works were identified and removed. In addition, 775 papers were removed since the title, keywords, or abstract did not show the desired themes. The criteria for removing the extra papers were i) the text not being related to medical science education and ii) the paper's failure to refer to any type of mobile learning intervention. Totally 95 papers were remained in the third phase (eligibility) and then 72 papers were excluded based on the inclusion/exclusion criteria. At the final phase (inclusion), 21 papers were selected for further analysis of which none was excluded in quality assessment (Figure 1).

Data extraction

The extracted data was the authors' name, year of publication, country, objectives of the study, participants, sample size, and summary of the results (Supplementary file).

Quality assessment of studies

Each article entering the study was examined in terms of methodological quality using the tools whose validity had been supported by the BEME Review on Education Portfolio. The tool is part of our data extraction sheet and includes 11 quality indicators about appropriateness of the study design, results, analysis, and conclusions, which are used to examine the quality of the studies. The tool is recommended for quantitative, qualitative, and combined method research in medical education (19). The studies that met a minimum of eight of these quality indicators were categorized as high quality, those that met six or seven criteria as medium quality, and those that met five or fewer criteria as low quality studies (20).

Synthesis of extracted evidence

For the adequately homogeneous data –i.e. studies with similar interventions, comparisons, outcomes, and study design- standard methods for meta-analysis (Cochrane Handbook) were employed. Still, according to the other systematic review in the medical education literature, it is

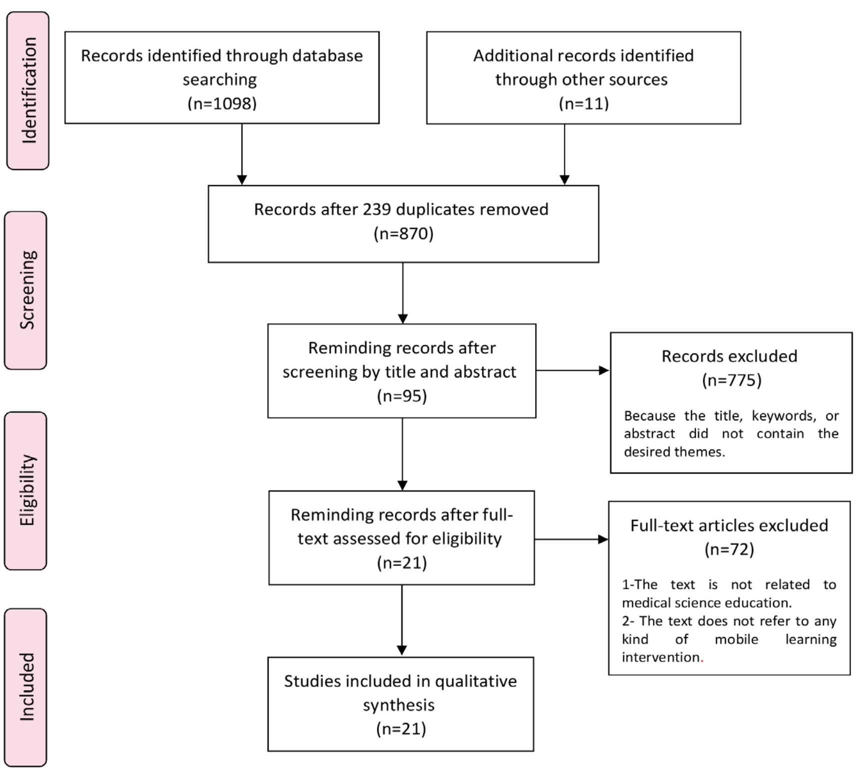

Figure 1: A study flowchart demonstrates the inclusion exclusion process

assumed that the collected data may be extra-heterogeneous, which makes it improper to be mixed for quantitative statistical meta-analysis. If so, a qualitative review of the evidence would be carried out through grouping and reporting studies using Kirkpatrick hierarchy introduced by BEME for educational contexts (21).

Results

Based on a systematic review of the educational papers published from 2007 to 2017 on mobile learning in medical education, 21 experimental studies were extracted, which were used to form the basis for answering the questions of the study.

Research methods

Six approaches were found for conducting research in the reviewed studies. The most commonly used approach was pre-test/post-test nonequivalent group (Table 3). The design is a quasi-experimental design and the subjects are not randomly assigned to the test and control groups. In addition, the two groups receive a pre-test and a post-test and the intervention will be carried out only for the test group.

Countries of research

Based on the results, South Korea is the top country in terms of the number of studies (n=5), and Iran (n=4), United States of America (n=3), Spain (n=2) are next in the list. The United Kingdom, Switzerland, India, Germany, Canada, Brazil, and Taiwan were represented only in one article

Population

In terms of the professional groups in the mentioned 21 articles, mobile learning was mostly used by the medical students (n=9). In two studies, the subjects were mixed (medical students and residents). In other studies, the samples were nursing students (n=8), dental students (n=3) and physiotherapy students (n=1).

Methodological quality

There were 11 high quality papers, 10 medium quality papers, and no low quality papers in the present study. Regardless of profession, higher quality papers were among the more recently published ones. All papers were compared based on the 11 quality indicators in figure 2.

Table 3: Design of studies

Design	Number
Quasi-experimental designs	
Pre-test/post-test nonequivalent group design	9
The post-test-only nonequivalent group design (The static-group comparison design)	4
The one-group pre-test/post-test design	1
Crossover method	1
True experimental designs	
The pre-test/post-test control group design	4
The post-test-only control group design	2

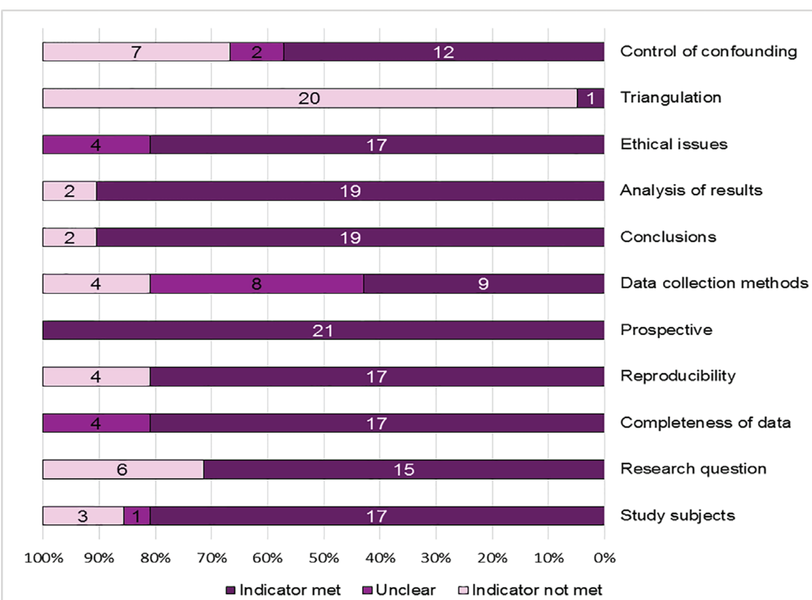

Figure 2: Quality of included studies

The most commonly met indicators were appropriateness of perspective, analysis of results, and conclusions of data. Still, in many occasions, data collection method (if the data gathering method was reliable and valid for the question of the study and context) was not clear due to insufficient data. Clearly, because of quantitative nature of the paper in this work, a low triangulation is expected.

Kirkpatrick outcome levels

The proportion of papers that evaluated the effect of mobile learning at each Kirkpatrick outcome level is listed in Table 4. Changes in knowledge/skills (levels 2B) were reported in all papers and only two papers mentioned the evaluation of the transfer of students' learning over the term of mobile learning into their workplace (level 3) (17, 22). Moreover, seven articles reported two or more outcome levels (3, 15, 17, 22-25). There was no report on the effects on the system/organization or patient care outcome as a direct outcome of the knowledge, skills, and attitudes developed by the subjects in the mobile learning (level 4).

Synthesis of findings

The outcomes of mobile learning are synthesised in the following sections based on the categories i) improvement in student clinical competency and confidence, ii) acquisition and enhancing students' theoretical knowledge, and 3) positive attitudes and perception of the students about mobile learning.

Improvement in student clinical competency and confidence

The way the mobile devices are employed for mobile learning and if they have any effect on students' clinical learning in medical sciences education were further examined. Thirteen papers were found in this area, which generally focused on how mobile devices including mobile phones and tablets might improve clinical learning among medical science students comparing with other traditional approaches. In general, there were several instances of positive effects of mobile learning utilization on clinical learning of students while some of them reported on the multiple benefits. There was a paucity of reports on neutral or negative effects. The fields that were affected by mobile learning included nursing process (22), patient presentations (17), catheterization (23), drugs calculation (26), maintain infant airway (15), communication skills (27), ultrasound and palpation of the shoulder region (28), the Epley particle repositioning manoeuvre (PRM) performance (29), fashioning rhomboid flaps (30), urinary catheter insertion (31), intramuscular injection (24), chest tube insertion (16), and clinical reasoning skills (32). In all cases, an improvement in performance of the students was observed after the intervention.

Acquisition and enhancing of student's theoretical knowledge

There were nine studies on the effects of mobile learning intervention on students theoretical knowledge and the summary of the results can be stated as follows; a positive effect on the cognitive aspects of medication error (33), the promotion of awareness on dental treatment of the patients suffering from systematic diseases (34), an increase in knowledge of the nursing students in nursing process (22), an influence on the final scores of the dental students in the course of oral pathology (35), a positive influence on the recall and transfer of visually transferred medical knowledge (in one case with sub capital facture of the fifth metacarpal bone) (36), greater knowledge acquisition for ethically sensitive students (37), higher subjective performance when rhomboid flaps are fashioned (30), improvement of their learning accomplishment with regard to the "respiratory system" as a part of the course for nursing students (25) and achievement of better scores in the anatomy course (38). Along with the aspects of theoretical learning, two of them influenced the practical aspects of learning that were mentioned earlier (22, 30).

Students' positive attitudes to and perception of mobile learning

There were eight studies on the effects of

Table 4: Distribution of reviewed studies based on Kirkpatrick outcome levels

Levels	Kirkpatrick outcome levels	Studies (n)
1	Reaction- learners' reactions	5
2A	Learning- Change in views or attitudes	2
2B	Learning- Modification of knowledge or skills	21
3	Behaviour- Change in behaviors (transfer of learning to the workplace)	2
4A	Results- Change in the system / organizational practice	0
4B	Results- Change in patient care outcomes	0

mobile learning on attitudes and perception about mobile learning in the subjects. We, et al. showed a significant increase in attitude in long run after the intervention so that the majority of the subjects had positive evaluation about the "ease of use" and "usefulness" of the mobile learning system (25). Jeong (2017) demonstrated a significant increase in satisfaction scores comparing with the baseline and after the mobile learning intervention (24). Lee, et al. (2016) indicated that the intervention group had a notable increase in learning motivation and class satisfaction comparing with the control group (23). Pimmer (2013) reported that the students in mobile learning groups found the support by the specialist significantly more positive than that evaluated by those in the control group (36). De Sena, et al. (2013) reported that all the subjects found the mobile platform multimedia learning the best study tool (30). Moreover, Deshpande, et al argued that there was an overall positive reaction to mobile prosthodontics application in more than two-thirds of interns (32) (Table 5).

Table 5: Summary of reviewed studies

Author et al. (year)	Country	Aim of the study	Participants	Design	Main findings
(30)	Brazil	Develop, validate, and evaluate feasibility of a multimedia software application designed for mobile platforms to help the teaching and learning process of skin flap surgery.	Medical students (N=50)	The pre-test/ post-test control group design	Comparing with those taught with standard print material, the test group showed better subjective (post-test) and objective performance in fashioning rhomboid flaps.
(29)	Canada	To show if using mobile application (DizzyFIX) had a significant impact on the performance of the Epley particle repositioning maneuver (PRM) by the medical students.	Medical students (N=41)	The post-test-only nonequivalent group design (the static-group comparison)	Mobile application users achieved significantly higher score in Epley particle repositioning maneuver (PRM) performance comparing with controls.
(37)	Germany	To determine the effects of a self-developedmobile augmented reality blended learning environment (mARble) for ethically sensitive subjects in particular such as forensic medicine and to compare the results with textbook learning in medical students.	Medical students (N=10)	Pre-test/ post-test nonequivalent group	The mobile augmented reality blended learning environment (mARble) group showed significantly higher knowledge gain comparing with the control group of the ethically sensitive subjects.
(32)	India	To determine the effects of a mobile learning application to teach clinical decision making in prosthodontics.	Dentistry students (N=120)	Pre-test/ post-test nonequivalent group	Clinical decision-making in prosthodontics with a mobile learning app is an efficient way to improve clinical reasoning skills for planning prosthodontics rehabilitation in dentistry students.
(33)	Iran	To examine the effects of clinical training using mobile phone (mobile application for drug use, common heart diseases care and other relevant information) on medication errors made by the nursing Trainees.	Nursing student (N=60)	Pre-test/ post-test nonequivalent group	Mobile medical software featured with regular training in clinical fields had a positive effect on the cognitive aspects of medication error in nursing students.
(34)	Iran	To study the impacts of using mobile educational software (DMOTMC) in improving students' awareness about dental treatment of patients with systemic diseases.	Dentistry student (N=60)	Pre-test/ post-test nonequivalent group	The mobile educational software (DMOTMC) group showed significantly higher awareness about dental treatment of the patients with systemic diseases gain comparing with the control group.
(22)	Iran	To evaluate nursing students' perspectives about a mobile software on nursing process for bedside usages.	Nursing students (N=30)	The one-group pre-test/post-test design	There was a significant increase in the rate of nursing process implementation, knowledge and skills of nursing students in nursing process after utilizing the software.

(35)	Iran	To study the effects of mobile-based education on dental students' learning in oral pathology course.	Dentistry students (N=30)	Crossover method	Mobile-based teaching was significantly effective on dental students' learning and final scores in course of oral pathology ($p<0.05$).
(23)	South Korea	To determine the effects of a mobile-based video clip on learning motivation, competence, and class satisfaction in nursing students.	Nursing students (N=71)	The pre-test/ post-test control group design	There was significant increase of learning level and satisfaction with class in the experiment group compared to the control group.
(15).	South Korea	To examine the effectiveness of using the application on nursing students' knowledge, skills, confidence and satisfaction in maintain infant airway in simulated situation.	Nursing students (N=73)	The pre-test/ post-test control group design	The experiment group showed significantly higher scores of maintaining infant air way skills, confidence in performance, knowledge and satisfaction comparing with the control group.
(27)	South Korea	To examine the effects of teaching communication skills using a video clip on a smart phone on communication competence and emotional intelligence in nursing students.	Nursing students (N=87)	Pre-test/ post-test nonequivalent group	Improvement in the experimental group was more significant than that of the control group in communication competence and emotional intelligence.
(24)	South Korea	To determine the effects of learning using smartphone video recordings in general "intramuscular injection" practice.	Nursing students (N=76)	Pre-test/ post-test nonequivalent group	The experimental group showed a significant improvement of intramuscular injection practice competency and learning satisfaction.
(3)	South Korea	Comparing the effectiveness of a high-fidelity human patient simulator with a mobile application designed for cardiopulmonary assessment education on student learning.	Nursing students (N=22)	Pre-test/ post-test nonequivalent group	A mobile application designed for cardiopulmonary assessment education improved maintaining the knowledge retention and provided clinical assessment skills similarly effective to a high-fidelity human patient simulator.
(28)	Spain	To determine if a mobile application, as a supplementto traditional learning, is effective for physiotherapy students in the acquisition of palpation and ultrasound skills in the shoulder area.	Physiotherapy students (N=49)	The post-test-only control group design	The experimental group achieved significantly higher scores than the control group for almost all items in the ultrasound assessment; positioning of patient, positioning of ultrasound probe, handling of ultrasound probe and global OSCE and skills in palpation of the shoulder; position of patient, direction of palpation contact and global OSCE.
(38)	Spain	To examine the results of using an anatomic app for learning and compare them with the formal traditional method conducted by a teacher.	Medical students (N=30)	Pre-test/ post-test nonequivalent group	The experimental group showed higher anatomicperformance than the students using the traditional method.
(36)	Switzerland	To examine effectiveness of different synchronous smartphone-based modes of communication, such as (1) speech only, (2) speech and images, and (3) speech, images, and image annotation (guided noticing) on the recall and transfer of visually and verbally represented medical knowledge (in a patient with a subcapital fracture of the fifth metacarpal bone).	Medical students (N=42)	The post-test-only nonequivalent group design (the static-group comparison)	The results show the use of guided noticing (the integration of speech, images, and image annotation) leads to significantly improved knowledge gains for visually represented knowledge.

(25)	Taiwan	To examine effectiveness of mobile learning activities for diagnosing the diseases of respiratory system based on the repertory grid approach.	Nursing students (N=48)	Pre-test/ post-test nonequivalent group	The results showed that the innovative approach was helpful for improving learning achievements and diagnosing diseases of the respiratory system.
(26)	United Kingdom	To examine a drug calculator on a smartphone and compare it with the British National Formulary for Children (BNFC) in terms of accuracy, speed and confidence of prescribing.	Medical students (N=7) and residents (N=28)	The post-test-only nonequivalent group design (the static-group comparison)	Participants showed higher confident in their prescription using the drugs calculator on the smartphone compared with the British National Formulary for Children.
(17)	United States of America	To evaluate medical students' case presentation performance and perception provided with short, just-in-time mobile learning videos in the iPod touch before encountering patients.	Medical students (N=22)	The post-test-only nonequivalent group design (the static-group comparison)	The results showed a statistically significant improvement in medical students patient presentations, when they watched the videos for the first time.
(31)	United States of America	To examine if instructional videos provided by iPod regarding female and male urinary catheter insertion increase students' confidence levels and enhance skill competencies.	Medical student (N= 21)	The pre-test/ post-test control group design	Video iPods improved medical students' skill competencies and self-confidence levels as to female and male urinary catheter insertion.
(16)	United States of America	To determine if using mobile learning module improves skills in chest tube insertion in medical students.	Medical students (N=42) anesthesia residents (N=44)	The post-test-only control group design	The subjects in the test group who watched the video had significantly better scores on the chest tube insertion skills checklist than the control group.

Discussion

This systematic review was aimed at searching, analyzing, and synthesizing experimental articles on mobile learning in medical science education from 2007 to 2017. To the best of the authors' knowledge, this study is the first work of this nature.

In general, using mobile learning for medical science students has mainly been documented in medical sciences education so that a variety of educational intervention, with different duration, frequency, and format have been conducted in different settings.

The rigour of studies on the evaluation of mobile learning educational outcomes has been previously reported as relatively weak, mostly about the limited tools utilized to measure learning results. The major part of the reports on changes in attitude or behavior have mainly relied on self-statements by the students (39). Moreover, increase in skill competency is a function of different factors such as prior knowledge and skills or trainings, exposure to limiting factors and organizational culture and the support provided to mobile learning. Some of the articles examined here failed to take these potentially confounding factors into account. Thus, it is not easy to determine if these effects, if any, are because of the intervention.

In addition, in published studies the period of the mobile learning interventions varying form some minutes to even months was not related to the educational outcomes. So, a significant subject that should be carefully studied in future research is the frequency of the delivery of the intervention as continuous or repeated interventions and its effect on the educational outcomes. In many studies, the interval between pre-test and post-test was very short which may lead to recall bias, meaning that we need further better methodologies and longer duration researches of mobile learning to determine its educational effects on the students.

None of the articles under study mentioned changes in organizational practice or improvement in patients' health results as a direct effect of mobile learning (Kirkpatrick's 4 levels). However, this is an ordinary practice in medical education reviews. Knowing this, such level of evaluation needs a long term follow-up and it is not feasible to take into account the complexity of the factors that affect the practice of patient care.

Using smartphone by medical students as a learning aid for different medical usage is advancing with high pace (40). However, studying if using smartphones has any effect on the grades of the students is imperative. The general consistency of the results among the articles regardless of the country in which the study had been conducted makes the results generalizable both in theoretical and clinical fields. All the papers examined by this study mentioned evidence of a variety of educational advantages of mobile learning in medical sciences students. Among these advantages are improvement of clinical competency and confidence of the students, improvement of theoretical knowledge acquisition, and positive attitudes and perception in the students about mobile learning.

The review indicated that the mobile learning can be used as a learning aid for all three domains of Bloom's taxonomy –i.e. cognitive, psychomotor and affective- for the students in medical sciences programs. An easy way to describe the required degree of understanding and using concepts, to have particular skills, and to influence their values, attitudes, and interests is Bloom's Taxonomy (41).

In addition to intellectual capacity or the type of software, the learners' attitudes about mobile learning are effective. Having a positive attitude increases enthusiasm, improves self-esteem, and develops an atmosphere that suits learning, which can, in turn, improve educational achievements (42). Regarding this, the reviewed papers noted that the subjects had positive response, attitudes, and satisfaction about mobile learning. Two papers reported that having direct contact with mobile learning experience and employing it for academic objectives improved attitudes and satisfaction in the student with regard to mobile learning (24, 25). Such general positive response and attitudes toward mobile learning is rooted in the fact that almost all students today have a mobile phone in their pocket.

Our results contribute to the achievement of a better planning and design of an efficient mobile learning using smartphones and other mobile devices in medical sciences education. The systematic review was an attempt to give a general picture of the extent of intervention suggested in the literature and give the trainers the best and last evidence to select the best intervention(s) in medical science curriculum. Using the findings, the students will also better enjoy the advantages in their academic, clinical, and professional endeavors. They will also be prepared for future licensing requirements.

The main points that medical sciences education policy makers and practitioners need to take into account in the design of a proper program and policy in which technologies in clinical and theoretical education are integrated are provided by this review. The findings also enable the policy makers to make better decisions about the topic. Moreover, the results achieved here can be used as a base for further studies and expansion of knowledge in this field. Future studies on different groups of students of medical sciences and countries need to focus on standardized and validated evaluation tools in randomized controlled trial settings. Through this, such studies can generate general reliable evidence with higher generalizability rate and based on which the most effective interventions and practices in mobile learning can be decided about. While the rapid growth of utilization of mobile learning is undeniable, there was clearly a paucity of evidence about the effects of mobile learning on patient outcomes (Kirkpatrick outcome level 4). The topic is a developing field of study and more studies need to be conducted to examine the effectiveness and/or economic aspects before improving care efficiency and patient outcomes. Moreover, it is not clear if the long-term retention of knowledge and skills is achievable using mobile learning. Therefore, to illuminate the causal effects and the retention effects of mobile learning, a longitudinal design study is needed.

Limitations

With regard to the limitations of the study, the lack of meta-analysis is notable; however, a meta-analysis was not possible because of the wide range of different study designs, tools, and outcomes, and the nature of the results reported. Because of language and availability limitations, missing some studies is possible. A checklist with 11 quality indices was used to determine quality of the articles under study. A requirement would be assumed as met or unmet only when the text is clear about the subject. In addition, no assumption was made with regard to the methodology for which the text was not clear. Taking into account that methodological and reporting quality cannot be assumed as synonyms (43), in some cases, an indicator might have been met but not mentioned clearly in the text. If so, quality of the study could be underestimated. At any rate, it is believed that the adopted approach was valid enough knowing that the paper results were the only available evidence to make a judgment about appropriateness of the study.

Conclusion

Our results demonstrated that mobile learning approach encompasses all the three domains of Bloom's Taxonomy – i.e. cognitive, affective, and psychomotor. The findings indicated positive attitudes and responses of the medical science students toward mobile learning so that using the technology can bring critical educational advantages that potentially enhance clinical competency and confidence, theoretical knowledge, attitudes and perceptions about mobile learning.

Conflict of Interest: None declared.

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