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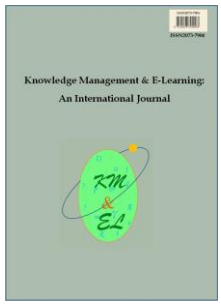

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Trends in smartphone-supported medical education: A review of journal publications from 2007 to 2016

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Abstract: Issues relevant to smartphone-supported mobile learning have been extensively discussed and investigated over the past years. Unlike general mobile devices, the advantages of smartphones, such as recording learning and portability, can cross formal and informal education. Smartphones can promote communication between health professionals; however, there is still a lack of systematic analysis of the application and development trends of smartphone use in medical education. The present study systematically reviewed research articles published in international academic journals from 2007 to 2016, analyzed the application domains, subjects, and adopted learning strategies, and investigated the research issues of smartphone-supported medical education. The findings revealed that the application of smartphones in medical education and training has not gained much popularity over the past years. In addition to the changes in the software technology in smartphones and the rising number of studies on mobile learning in medical education, research issues have become increasingly diverse in recent years. Smartphone-supported learning has mainly been implemented to develop basic concepts of biomedical information and in information technology environments; moreover, applying smartphones in medical education did not extensively adopt such learning strategies as inquiry-based learning, contextual mobile learning, mindtools, game-based learning, or synchronous sharing. This indicates that most of the studies adopting smartphones focused on skills training and basic knowledge acquisition rather than on the development of learners' higher-order thinking, for example, problem solving or critical thinking. On the other hand, it was found that the number of experimental studies related to smartphones has increased recently. The majority of research adopted questionnaire surveys and reported learners' cognitive performances and concepts, while learning behaviors were seldom analyzed. Therefore, this study indicates the research trends and potential research issues of integrating smartphones into medical education, and provides suggestions and references for researchers, medical teachers, and decision-makers.

Keywords: Literature review; Smartphone; Mobile learning; Medical education; Trend analysis

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1. Introduction

The advancements in wireless Internet, sensing technology, and mobile technology have brought about innovative changes for instructors and learners; the development of wireless communication and sensor technologies in smartphones provides new perspectives of research in the field of digital learning and education (Hwang, Wu, & Chen, 2007). Compared with general mobile devices, smartphones have the advantage of being able to cross formal and informal education; they differ from other mobile devices as, for example, people may not bring tablet computers with them except for formal learning. As a result, the current study aimed to review the literature on smartphones in education.

By examining the current literature, it was found that more research was relevant to smartphone-supported formal learning than informal learning. It is extremely important to understand how medical staff learn through smartphones when they are on the job, and how they keep learning via their smartphones after work. In addition, smartphones can offer better opportunities for delivering health and medical knowledge to patients and their families. It might be impractical to expect patients and their family members to bring a tablet computer with them for learning; on the other hand, smartphones are almost always with them.

Sandholzer, Deutsch, Frese, and Winter (2015) implied that smartphones are playing an increasingly important role in daily life. The iPhone and Android devices released in 2007 and 2008 demonstrated the success of the smartphone business (Gozalvez, 2008; Oehler, Smith, & Toney, 2010). Therefore, it is becoming more and more important to consider potential of integrating smartphones into the domain of medical care. In the past decade, smartphones have caught the attention of researchers and developers who are interested in their application in medical care and who have already examined and developed smartphone applications (apps) such as physical activity tracking, patient monitoring, diagnosis and measurement, just to name a few (Cho, Sim, & Hwang, 2014; Nishiguchi et al., 2014). However, the potential of applying smartphones in medical education remains to be explored (Sandholzer, Rurik, Deutsch, & Frese, 2014). The majority of people have a smartphone with them all the time, so the devices can provide an ideal platform for medical education (Boeder, 2013). Smartphone-supported learning can flexibly explain the evaluation of medical guides to students, and take advantage of waiting time as a way for contemporary students to effectively

familiarize themselves with the content of the materials (Waldmann & Weckbecker, 2013).

Researchers have made attempts to instruct students in integrating the knowledge in textbooks into real-world contexts through the mobility of mobile technology; students can immediately receive messages and gain knowledge by repeatedly watching and learning through their smartphones, which makes the devices more valuable than traditional learning resources (Davies, Rafique, Vincent, Fairclough, Packer, Vincent, & Haq, 2012). Consequently, some scholars have proposed that medical teachers should incorporate smartphones into traditional learning tools and train students to solve problems by applying their knowledge via the smartphones. In fact, educators should adopt this measure (Trelease, 2008) and verify its influence on students' test scores.

Technology is bringing numerous revolutionary changes to all domains and disciplines in the 21st century. Apart from incorporating mobile learning curricula into general disciplines, integrating mobile technology into medical education is another notable issue. Innovative integration of technology can not only assist medical students in effectively learning in the limited clinical teaching time, but can also help medical personnel carry out professional skills training and strengthening. For example, Konings et al. (2016) constructed smartphone apps and randomly distributed them to 64 residents. They held training courses to undergo counseling interviews once every two weeks, and evaluated the strength of the smartphone apps and counseling courses and the users' reflections. Through the portability of smartphones, they guided the learners to integrate learning tools in the workplace into counseling courses as their personal digital educational training. Additionally, Wittich et al. (2016) implemented smartphones in continuing medical education (CME) courses and underwent cross-sectional learning surveys on topics in an Internal Medicine Course. They adopted the CME application attitudes survey instrument to investigate conference participants' attitudes toward the application of smartphones in the meeting; the findings showed that the participants unanimously agreed with the convenience of integrating smartphones into the conference.

The results of experimental studies have revealed that students instructed using smartphones outperformed those using a traditional learning approach in terms of distinguishing diseases. This confirmed that smartphone-supported learning can effectively enhance students' learning achievement. For instance, Patel, Green, Shahzad, and Larkin (2015) made use of smartphones and the Internet to have two-way interaction and responses after sending and receiving instant medical information. They proposed that clinical decision support (CDS) tools can improve clinical diagnosis and patients' safety. In addition, smartphones can assist medical professionals in making judgements in the medical golden treatment time, and increasing clinical efficiency by allowing them to transmit and record medical information (Pimmer, Mateescu, Zahn, & Genewein, 2013). This indicates that integrating mobile technology such as smartphones can support the research examining students' learning in clinical medical environments (Alam et al., 2016; Briz-Ponce, Juanes-Mendez, Garcia-Penalvo, & Pereira, 2016; Kucuk, Kapakin, & Goktas, 2016). With the increasing innovations in technology, the medical and professional domains, which put emphasis on instant response and accuracy, can only avoid incidents and medical malpractice by practical learning and accumulated experience. Also, through the development of related studies and research discussion, this technology can be useful for training professional medical teams and enhancing medical quality.

In order to understand the application modes and trends of smartphones in medical education, the present study examined the literature which applied smartphones

in medical education from 2007 to 2016. According to the findings, we identified research issues for future medical education as references and suggestions for medical educational institutions and researchers to implement smartphones in medical education and to carry out related research.

2. Literature review

There are various definitions of mobile learning; scholars have defined mobile learning (m-learning) as "a teaching/learning approach which applies mobile technology-assisted learning" (Hwang, Tsai, & Yang, 2008). Others have pointed out that m-learning has the advantages of crossing geographical and time constraints compared to traditional e-learning (Phillippi & Wyatt, 2011). With the portability of smartphones, learners can read learning materials, practice, and search for data at any time; in addition, learning systems can provide learners with instruction and the required supporting materials according to their surroundings (Wu, Hwang, Tsai, Chen, & Huang, 2011), which is conducive to enhancing learning effectiveness.

Medical application of smartphones has attracted researchers' interest. For example, several studies have already explored the factors of mobile technology; for example, some researchers have examined the intention and index of using smartphones (Park & Chen, 2007), and have investigated the intention factors of the technology acceptance model driving the adoption of smartphone-supported mobile learning (Liu, Li, & Carlsson, 2010). In the medical domain, Woods, Dumbleton, Jones, and Fonn (2011) indicated that smartphones can increase the collection of medical data in medical studies. Yamada, Aoyama, Okamoto, Nagai, Tanaka, and Takemura (2011) implemented the accelerometer of smartphones to examine elderly people with a high risk of falling. A study in the United States explored the innovative factors which influence doctors' decisions to use smartphones (Putzer & Park, 2012). Sandholzer, Rurik, Deutsch, and Frese (2014) evaluated students' needs for general applications and the potential of such applications. They asked students to participate in empirical lectures as a tool for them to gain or intensify their knowledge, and administered simulation tests to prepare for the test. Their study examined the influencing factors of adopting smartphones in medical education, and compared the differences between their study results and those of previous literature. Scholars have implied that smartphones with medical apps certainly offer effective ways to communicate in areas with limited resources (Chang et al., 2012).

In the past, there have been numerous successful examples of applying smartphones in medical education. For example, Shaw and Tan (2015) implemented the UF Surgery Application for use with medical educational materials, integrated and improved participation and learning methods, and developed a new form of mobile learning in residents' modes. Additionally, Johnson et al. (2015) incorporated smartphones into the education in a medical center. They examined medical students' practices of using smartphones in medical institutions, and required doctors and medical students to complete an anonymous survey related to smartphone usage in all kinds of medical environments over the past month, specifying the use of smartphones in different surroundings. The majority of them used smartphones during breaks as they considered such problems as patients' treatment levels, the adequacy of behavior before patients, and their professional image. They seldom used smartphones when they were on call or in surgery. Jamal et al. (2016) conducted cross-functional and multi-center investigation on the usage situation of cellphones among medical staff. The researchers examined their attitudes, opinions, and challenges in academic and clinical practice. The results demonstrated that they unanimously consented to integrating medical staff's cellphones

into the hospital information system. The residents believed that it was safe to discuss patients through personal unencrypted emails, and conveyed that it was quite common to implement mobile phones in medical education in academic and clinical environments. Therefore, academic and medical institutions should protect patients' privacy and appropriately support conducting medical training and medical decisions using mobile devices at the same time.

By reviewing the literature, Ozdalga, Ozdalga, and Ahuja (2012) conducted a backtrack analysis of applying smartphones in medical domains, excluding surgical use. There were 60 studies which showed that smartphones had various applications in medicine. They further analyzed these articles and divided them into the following categories: (1) patient care and monitoring, (2) health apps for the layperson, (3) communication, education, and research, and (4) physician or student reference apps. It was noticeable that there were 24 articles in the category of "communication, education, and research;" It was found that only one example was relevant to medical education. In that study, the students had significantly improved scores during cardiac arrest simulation testing after receiving the instruction of advanced life support via smartphone apps (Low, Clark, Soar, Padkin, Stoneham, Perkins, & Nolan, 2011). Accordingly, Ozdalga, Ozdalga, and Ahuja (2012) suggested that smartphones could be incorporated into the primary stage of medical education, and it is crucial to decide how to deal with the development and evaluation modes.

In order to make related medical studies and training development smoother, knowledge of the previous applications and research trends of implementing smartphones in medical education is essential. The information provided from systematic literature reviews can assist researchers and educational institutions in better understanding the direction of research and instruction (Hwang & Wu, 2014). Therefore, in this study, a systematical review was conducted to examine the applications and findings of using smartphone technology in medical education from various perspectives.

3. Method

3.1. Data resources

The studies relevant to mobile learning in medical education between 2007 and 2016 were searched in the WOS database on September 5th, 2017. Limiting the search to SSCI and SCI papers, there were 145 including "mobile" and "medical training" or "medical learning" or "medical course" or "medical education" in the keywords list. Among them, 122 were journal articles. By removing 75 journal articles not related to the use of smartphones in medical education, a total of 47 papers were selected in the final list for analysis, as shown in Fig. 1.

3.2. Data distribution

Fig. 2 shows the publication situation of mobile learning in medical education papers from 2007 to 2016. The earliest paper was written by Trelease (2008); he conducted a practical investigation of medical education which examined the integration of Apple iPhone and media player capabilities in anatomical education. There were fewer than five papers on mobile learning in medical education between 1982 and 2011. It was not until 2012 that it started to receive more attention from researchers. In Fig. 2, it can be seen

that 16 papers related to mobile learning were published in the medical education domain in 2016. Such a finding is reasonable as medical students need to practice learning repeatedly at anytime and anywhere to gain medical knowledge more effectively due to the advancements in technology. In particular, in recent years, the rapid growth of mobile devices around the globe has encouraged schools and research institutions to employ mobile technology in learning and training (Kucuk, Kapakin, & Goktas, 2016; Konings et al., 2016). Meanwhile, the application of mobile devices and smartphones offers learning equipment which satisfies the needs of medical education. Apparently, mobile learning technology started to be extensively implemented in formal and informal education at this time.

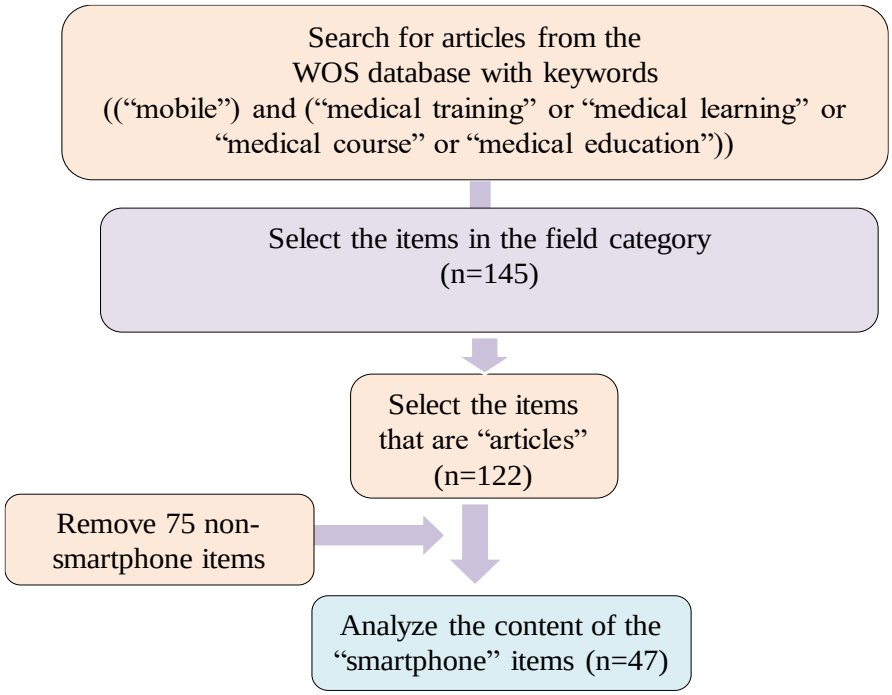

Fig. 1. WOS database searching process

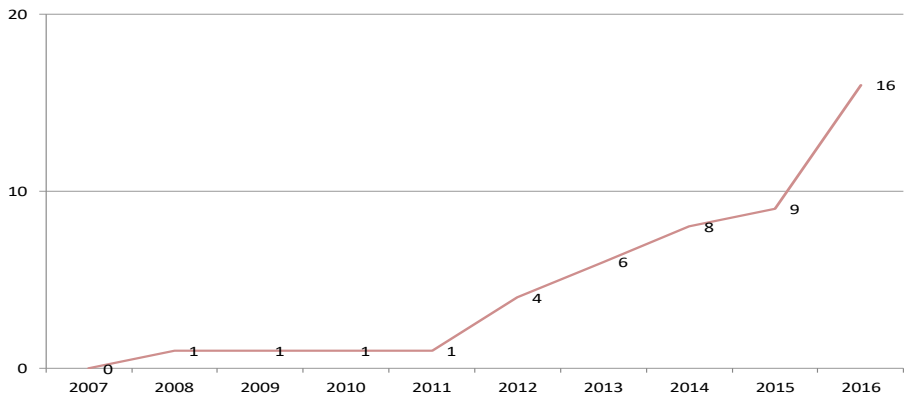

Fig. 2. The distribution of medical education smartphone studies from 2007 to 2016

3.3. Coding schemes

This study adopted the coding schemes proposed by Hwang and Wu (2014), Hwang and Tsai (2011), and Chang, Lai, and Hwang (2018), including the nationality, journals, application domains and forms, participants, research issues, research methods, and learning strategies. The following section explains the coding schemes of each dimension.

Nationalities and journals

We report the nationality and journals of the published papers in order to understand which countries have published papers on the use of smartphones in medical education in international journals.

Application domains and forms

The categories of medical specialist fields from Chang, Lai, and Hwang (2018) served as the reference for this study, namely information technology training, basic concepts and skills, long-term care, chest, critical care units/emergency health, cardiology, family medicine, neurology, pharmacology, evidence-based care, obstetrics & gynecology, orthopedics, pediatrics, psychiatric nursing, surgical ward, geriatric medicine, dermatology, otolaryngology, radiography, public health training, anatomy, clinical setting and forensic medicine.

Participants

The participants were categorized into students, patients, family, and the general public (Brown & McCrorie, 2015; Zayim & Ozel, 2015).

Research issues

In this study, we referred to Chang, Lai, and Hwang's (2018) categories and included the following aspects: affect, cognitive, psychomotor, learning behaviors, and causal analysis. The affect aspect means the participants' feelings about learning, while the cognitive aspect refers to acquiring knowledge from learning. The psychomotor domain indicates the professional skills in medical education which are used to examine whether students are able to operate the equipment or technology and apply knowledge to physical objects. The aspect of learning behaviors represents the investigation of participants' behaviors in the real world or in the virtual world, while causal analysis means the discussion of the relationship or effectiveness of participants' perceptions of medical education.

Research methods, participants, and research issues

The present study reviewed the research methods, participants, and researched issues adopted in mobile medical education studies. The categories of research methods were based on Johnson and Christensen's (2000) study, namely experimental design method, questionnaire survey, qualitative research method, system development, and document analysis.

Learning strategies

The learning strategies in this study were categorized and based on the common mobile learning strategies proposed by Lai and Hwang (2015), that is, guided learning, peer assessment, video sharing, synchronous sharing, issue-based learning, computers as mental tools, project-based learning, inquiry-based learning, contextual mobile learning, game-based learning, community service training, and satisfaction survey. Table 1 provides detailed explanations of these strategies.

Table 1
The classification and explanation of the adopted mobile learning strategies

Strategy	Explanation
(1) Guided learning	Through the supplementary learning materials, websites, and software, students are helped to collect and organize information, or practice.
(2) Peer assessment	Students are guided to grade and comment on peers' performance and works, based on the rubrics provided by teachers. In the activity, students play not only the roles of learners or interviewees but also the roles of teachers or interviewers.
(3) Video sharing	Students are guided to interpret, practice, and apply the learning contents by recording videos.
(4) Synchronous sharing	Students are guided to have in-time interaction through mobile technology, including discussion, sharing, and joint problem-solving.
(5) Issue-based learning	Students are guided to engage in data collection and online discussion, based on the assigned topics.
(6) Computers as Mindtools	Students are guided to use Mindtools (Computer-assisted learning tools) to summarize, organize, connect, and infer the knowledge.
(7) Project-based learning	Students are guided to complete the projects, based on the assigned topics, including reports or other forms of work.
(8) Inquiry-based learning	Students are guided to discover problems, to find the solutions, and to organize the knowledge.
(9) Contextual mobile learning	Students are guided to apply, observe, discuss the textbook knowledge, collect data, and solve problems in the real-world environment.
(10) Game-based learning	The gaming competition strategy is combined with mobile learning activities.
(11) Community service training	Learn by serving the patients on site.
(12) Satisfaction survey	No particular activity. Only questionnaires were used to collect data regarding learners' perceptions of using smartphones to learn.

4. Results

4.1. Nationalities and journals

With regard to all the published papers of mobile technology in medical education, only the nationalities of the first authors were considered in this study. From the results, it can be found that there were many researchers from different countries making attempts to apply mobile technology in medical education. Fig. 3 depicts that the top three countries and areas were the United States (30), the United Kingdom (10), and Germany (4).

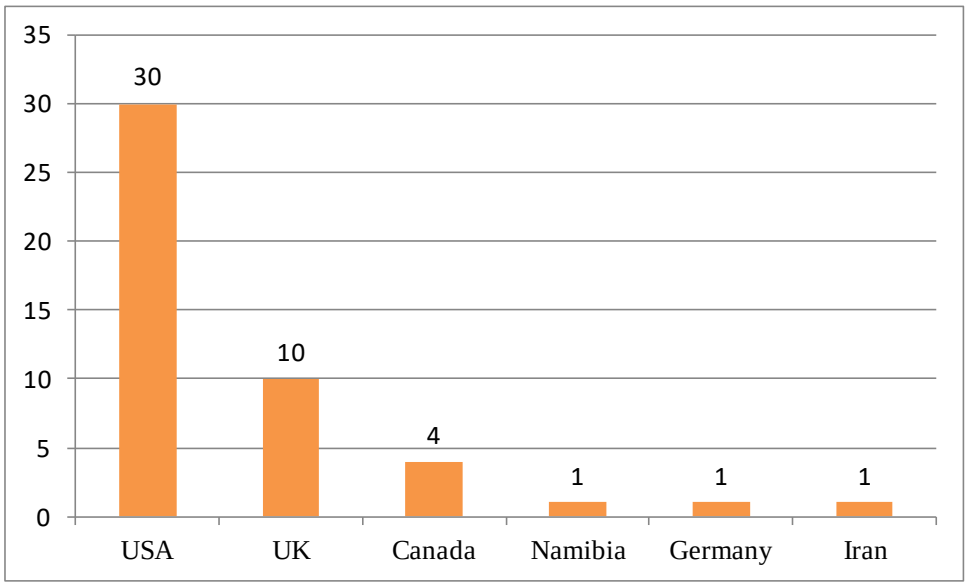

Fig. 3. The top three countries publishing papers on mobile technology in medical education from 2007 to 2016

The present study only considered the international journals with two or more papers on medical education published on smartphones from 2007 to 2016. Fig. 4 shows that they are BMC Medical Education, Anatomical Sciences Education, the Journal of Medical Internet Research, the Journal of Medical Systems, JMIR Mhealth and Uhealth, BMJ Open, the Journal of Continuing Education in the Health Professions, and Medical Teacher. The journal with the greatest number of published papers was BMC Medical Education, with a total of six, followed by Anatomical Sciences Education, the Journal of Medical Internet Research, and the Journal of Medical Systems, with a total of four papers each.

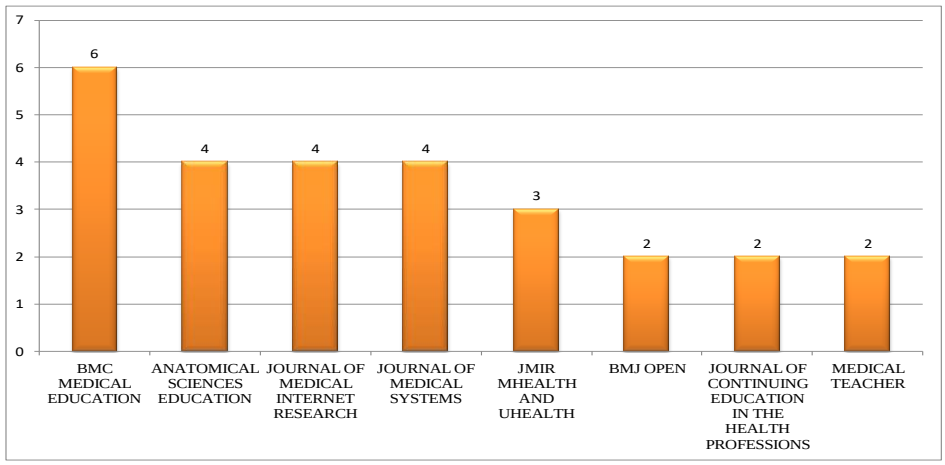

Fig. 4. Journals with two or more published papers on mobile learning in medical education using smartphones from 2007 to 2016

4.2. Application domains and forms

Fig. 5 shows the application domains of smartphones in medical education by reviewing the literature from 2007 to 2016. Among the 47 papers, 14 were about information environment; the second greatest number of papers (six) were relevant to evidence-based care.

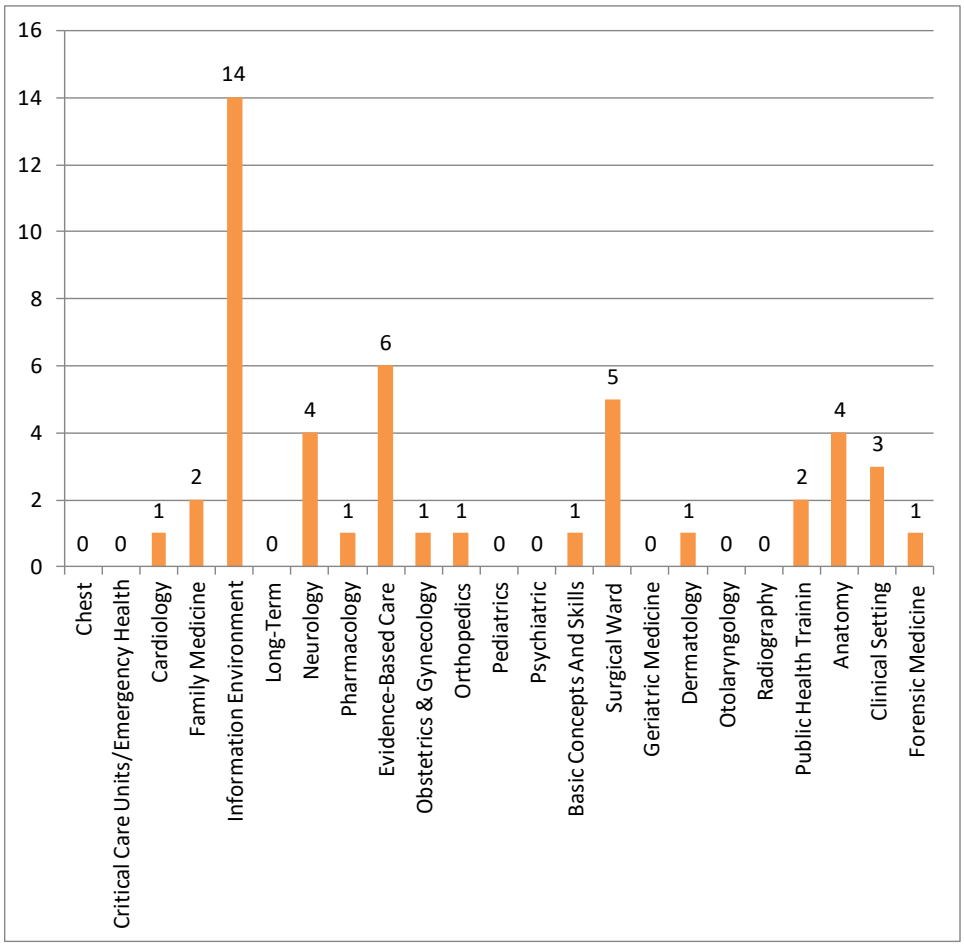

Fig. 5. Number of each application domain from 2007 to 2016

The examples of information environment can be seen in Fig. 5. For instance, Jamal et al. (2016) reported that all participants consented to integrate the cell phones of medical personnel into the hospital information system; it was pervasive to implement mobile phones in medical education in academic and clinical contexts. Academic and medical institutions should protect patients' privacy and at the same time appropriately support conducting medical training and medical decision making by way of mobile devices. As for evidence-based care, Avila, Sostmann, Breckwoldt, and Peters (2016) used an electronic portfolio system to record and support learning activities. The combination of the electronic portfolios and mobility could stimulate students to learn flexibly, specifying the enhancement of students' learning interest. With regard to clinical settings, researchers employed video recordings as students' training. The findings indicated that students who used mobile technology in medical education reported

positive learning outcomes and obtained enriched medical clinical learning experience (Konings et al., 2016). Other application domains or forms such as chest, critical care units/emergency health, long-term care, pediatrics, psychiatric, geriatric medicine, otolaryngology, and radiography have not yet gained the attention of researchers; these are suggestions for further research in medical educationysical proximity to other students and instructors (McInnerney & Roberts, 2004). Often times, they tend to feel lost in the cyber space. Therefore, they need help to overcome these challenges, especially when they inevitably and repeatedly face problems that require help from external resources including instructors, peers, websites, and video tutorials etc. As an important self-regulated learning strategy (Newman, 2008), help-seeking is found to be associated with increased student engagement in the learning process and positive academic outcomes (Barnard, Paton, & Lan, 2008; Rakes & Dunn, 2010). Further, help-seeking is listed as an important indicator of student college success (Karabenick & Newman, 2006). Unfortunately, many students are reluctant to seek help, partially due to motivation issues including achievement goals (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003; Ryan & Pintrich, 1998).

4.3. Participants

The participants of the studies were classified into students, patients, family, and the general public. The number of studies focusing on each group was 29 for students, nine for patients, one for family, and 11 for the general public (see Fig. 6). For the research papers targeting students, Dimond, Bullock, Lovatt, and Stacey (2016) employed smartphones in medical education; they used stethoscopes in teaching and guided students to learn anytime and anywhere. Additionally, Jamal et al. (2016) examined and analyzed the situation of medical students' cell phones. Academic and medical institutions should keep protecting patients' privacy, and understand students' perceptions of the system or certain problems at the same time.

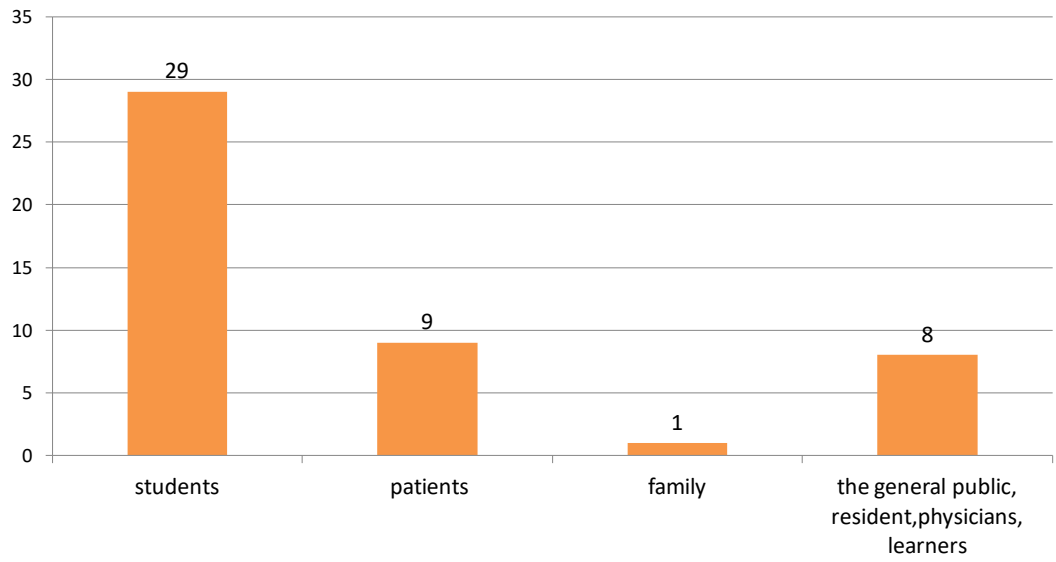

Fig. 6. The number of papers focusing on specific subjects in published medical education smartphone studies from 2007 to 2016

4.4. Research issues

The research issues in the studies on integrating smartphones into medical education were analyzed, including the aspects of affect, cognitive, psychomotor, learning behaviors, and causal analysis. Fig. 7 demonstrates the number of paper discussing each issue in the literature. It can be seen that studies on the affect aspect (23 papers) and on the cognitive aspect (19 papers) made up the majority of the studies. On the other hand, studies on the causal analysis (one paper), learning behaviors (two papers) and the psychomotor aspect (two papers) were considered during the period from 2007 to 2016 in medical education. In terms of the example on the affect aspect, Andrawis, Muzykewicz, and Franko (2016) conducted a questionnaire survey to investigate the trainees' and doctors' smartphone usage in clinical contexts. They analyzed the results from plastic surgeons and students for 48 months. Smartphones have become one ubiquitous tool for plastic surgeons and students, which encouraged providers and trainees to be aware of the inherent limitations and risks of new technology and to implement it in measuring and explaining medical education. This finding also indicates that understanding the application trends of smartphones could continue the situation of their integration in medical education.

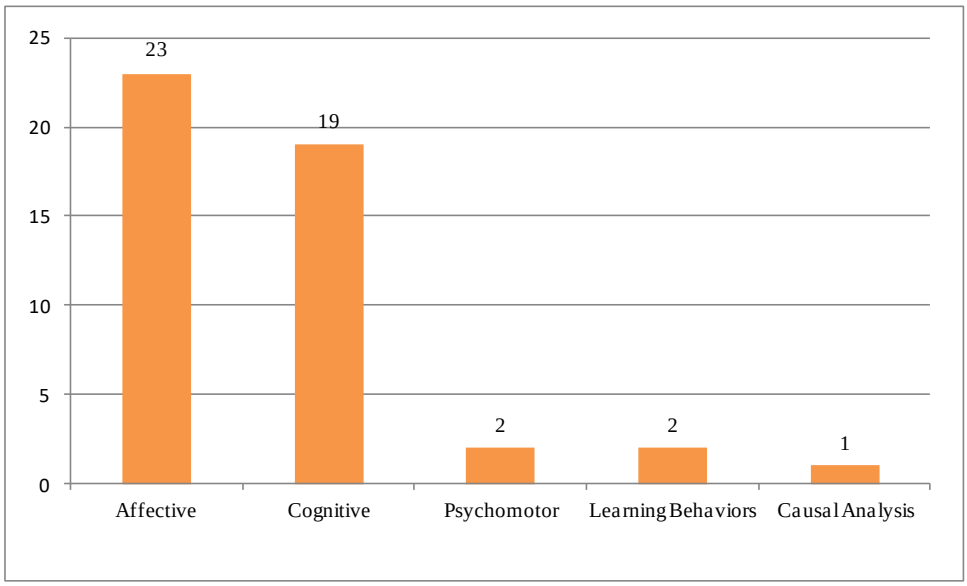

Fig. 7. Research issues in medical education studies from 2007 to 2016

4.5. Research methods

Fig. 8 shows that among the 47 chosen papers, 23 adopted the experimental design method, aiming to examine the influences of the proposed system or learning strategies on the participants, while 16 employed the questionnaire survey method, meaning to investigate participants' preferences regarding the commonly used smartphone technology in medical education. There were six papers using the qualitative research method, including a focus group interview, case study, or other qualitative methods. Additionally, two papers adopted document analysis to explore issues of mobile technology in medical education.

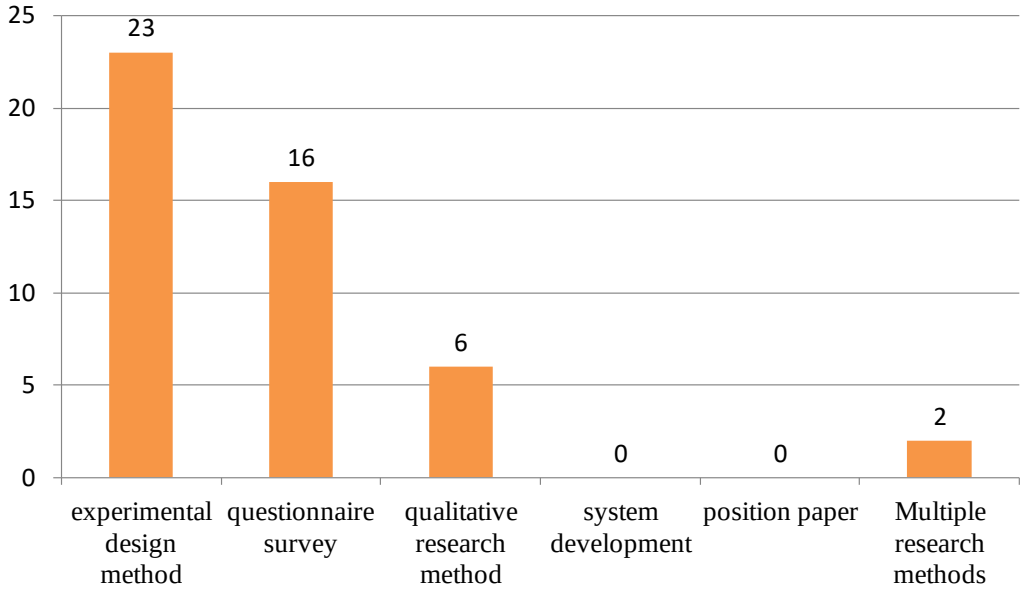

Fig. 8. Research methods adopted in medical education with smartphone studies from 2007 to 2016

With regard to the examples of studies on smartphones adopting the experimental design method, Pimmer, Mateescu, Zahn, and Genewein (2013) examined the value of smartphones for inter-clinician communication and knowledge processes, and indicated the different effects of synchronous smartphone-based modes of communication. The experiment was conducted with 42 medical students in a Master's program; all of the participants analyzed a standardized case (a patient with a sub-capital fracture of the fifth metacarpal bone) according to a radiological image, photographs of the hand, and textual descriptions. They were randomly assigned and were asked to consult a remote surgical specialist via their smartphones. To evaluate knowledge recall, participants were required to summarize the case and re-analyze the diagnostic images (visually represented knowledge) after the consultation. To assess knowledge transfer, the participants verified the value of digital and mobile technology for inter-clinician communication and medical informatics.

4.6. Learning strategies

In the medical educational activities, the distribution of the adopted learning strategies on mobile technology studies is shown in Fig. 9. The greatest proportion of papers adopted surveys, with a total of 20 papers, followed by guided learning, with a total of 19 papers. Pimmer, Mateescu, Zahn, and Genewein (2013) instructed students to consult with a remote surgical specialist via smartphones in order to obtain diagnostic images and visually represented knowledge. The study guided learning and interaction by flexibly applying smartphone devices; this development might be connected to the increasing popularity of mobile devices and wireless Internet. This literature review found that guided learning was the only learning strategy that was frequently adopted, meaning that more diversified learning strategies integrated with technology should be designed to increase students' learning opportunities.

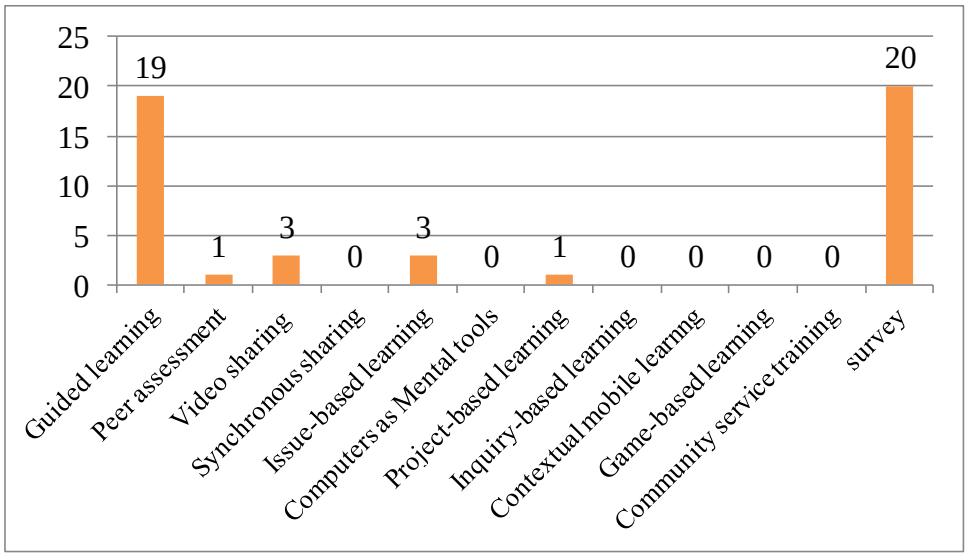

Fig. 9. Learning strategies adopted in mobile medical education with smartphones from 2007 to 2016

5. Conclusion & discussion

In this study, a systematic review was conducted by analyzing the mobile learning studies in medical education published in international journals from 2007 to 2016 extracted from the WOS database. It was found that the number of papers increased significantly over the past decades. It was also found that numerous studies reported the positive influences of mobile learning on students' performances and points of view in medical education (Alam et al., 2016; Briz-Ponce, Juanes-Mendez, Garcia-Penalvo, & Pereira, 2016; Kucuk, Kapakin, & Goktas, 2016), demonstrating the potential of using smartphones for improving learners' performance in medical training courses.

Meanwhile, it was discovered that there was little research investigating the issues related to "learning behavior," revealing that more studies should be done to analyze learners' behaviors recorded during the learning process, such as evaluating their learning performance or higher-order thinking (e.g., critical thinking). This implies that examining the effects of mobile learning approaches on learners' higher order thinking in medical education remains a challenging and crucial issue. Besides, the aspect of affect, for example self-efficacy and learning anxiety, was seldom discussed.

Furthermore, as the statistics showed, several medical education domains have seldom been investigated, such as the health education and technology application of emergency medical networks in remote areas, global population aging, and the long-term care field. Thus, it is worth investigating the influences of mobile technology on learners' performance in a wider range of medical education domains.

As for the participants in these domains, Chang, Lai, and Hwang's (2018) literature review already analyzed studies involving nurses; however, such medical personnel as pharmacists, radiologists, medical technologists, occupational therapists, physical therapists, clinical psychologists, counselors, respiratory therapists, midwives, dieticians, audiologists, speech language pathologists, and dental technicians have seldom

been examined. It is worth exploring the effects of smartphones on learners' performance in these medical education domains.

It was found that learning strategies were seldom adopted in mobile medical education. In the past decade, numerous studies have indicated the effectiveness of using these strategies in mobile learning (Hwang & Wu, 2014); as a result, it is worth attempting to explore the possibility of applying smartphones in medical education. In particular, inquiry-based learning, contextual mobile learning, Mindtools, game-based learning, and synchronous sharing could benefit learners in terms of their higher-order thinking, for example, problem solving and critical thinking.

From the abovementioned discussion, suggestions for future applications of smartphones in medical education are as follows: in the chest, critical care units/emergency health, long-term care, pediatrics, psychiatric, geriatric medicine, otolaryngology, and radiography areas, the training of several skills could be considered, for instance, interpretation of thoracic physiology examination, emergency critical medical network rescue, ACLS teaching, physical examination, and the interpretation of pathology reports, to name just a few.

Learning strategies such as computers as mental tools, game-based learning, and contextual mobile learning could be adopted into mobile medical education. In the meantime, possible approaches to implementing these learning activity strategies in mobile medical education could be considered, for example, applying computers as mental tools to teach medical personnel to have the capabilities of cross-team communication and shared decision making (SDM) in intensive care units (ICU), applying contextual mobile learning to teach medical personnel to have the ability of emergency rescue training, applying game-based learning to instruct medical personnel to be more sympathetic and caring of the children in pediatrics, and applying smartphone identification in geriatric medicine to improve the correct rate of administration and enhance the professional image and medical quality.

It is also important to design effective mobile learning activities to promote learners' higher-order thinking in medical education, such as problem-solving ability, creativity, and critical thinking ability. Learners' behaviors and interactive patterns in mobile learning activities in medical education can be analyzed to understand the relationship between their behavioral patterns and learning effectiveness. It would also be useful to explore the effects of teachers', students', and other groups' personal factors, teaching experiences, and technology self-efficacy for mobile technology acceptance in mobile medical education. More effective mobile learning modes and strategies can be proposed in medical education, for example, applying a combination of mobile technology and the flipped learning mode to let students learn ubiquitously, and to train and evaluate the effects on medical professional knowledge, skills, and self-learning performance of a new generation of medical personnel. It is important to analyze the possibilities of employing different types of technology in medical education. For example, the benefits of applying the Global Positioning System (GPS) in regional medical education and the new research issues, RFID and QR-code could help medical personnel to identify the patients, understand the medical environment and devices, learn the medical skills, and expand the medical education modes, learning strategies, or research issues.

On the other hand, it might not be appropriate to apply smartphones in mobile learning for some aspects of medical education, especially for the specialized technical training or the practical teaching under the operation of microscopes, for instance, puncture skills training, tracheal tube placement technology, thoracotomy, chest tube

placement technology, or dental implants. The training of precision medical skills where medical personnel are required to operate in clinical contexts is not a suitable training environment for the use of mobile learning. Nonetheless, the situation might be turned around if augmented reality technology makes progress in the future.

The research on mobile technology in medical domains has been growing rapidly; however, few studies have been conducted to answer the problems of the application and the possible influences of mobile technology. The applications for applied pharmacology, medical references, and other types can provide doctors with rapid and practical medical messages, which can benefit education and patient caring and improve the communication between hospitals and patients. Furthermore, it can assist developing countries in areas with poor resources in attaining better medical diagnostic tools. Smartphones have an extremely bright prospect in the medical domain; it is expected that they will lead to much healthier and better relationships between doctors and patients, and be regarded as a diagnostic and curing tool in the future.

The main purposes and contribution of the current study were to review and analyze studies related to medical education and mobile learning; possible future research issues have also been addressed. Because of the rapid development of mobile technology, medical professions are becoming increasingly diverse. Through mobile technology and the Internet of Things, 24-hour medical professional service is provided to improve the pattern of medical care. It allows professionals to make use of their technology to provide information for patients and consultation for health education, and support for those who require special care in order to improve the medical quality. A smartphone also provides another interactive way to exchange messages and a supporting channel for society. Other than the problems of budget and techniques, effective educational modes and learning strategies for applying mobile learning in medical care are important factors to determine learning achievement. Thus, in correspondence with the needs of learners in the 21st century, how to investigate the digital learning strategies in medical education, and how to develop more suitable mobile learning strategies and modes in medical education are issues worth investigating.

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