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Review Article

Effects of Smartphone-Based Mobile Learning in Nursing Education: A Systematic Review and Meta-analysis☆

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ABSTRACT

Purpose: A systematic review and meta-analysis was conducted to evaluate the effects of smartphone-based mobile learning for nurses and nursing students.
Methods: Electronic literature search of PubMed, Cochrane Library, Embase, SCOPUS, Web of Science, ProQuest Central, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Educational Resource Information Center (ERIC) was conducted. Two authors independently reviewed empirical studies for inclusion and extracted the design, sample size, intervention method, outcome variables, and statistical values of them. Methodological quality was assessed using Cochrane collaboration risk of bias tool. To estimate the effect size, meta-analysis was performed using R meta program.
Results: Authors identified 11 randomized or nonrandomized controlled trials of a total of 3,419 studies. Overall effect sizes by random-effects model was large [Hedges'g (g) = 1.12, 95% confidence interval (CI) 0.72–1.52], with learning attitude (g = 1.69), skills (g = 1.41), knowledge (g = 1.47), and confidence in performance (g = 1.54). For heterogeneity, subgroup analyses using meta-analysis of variance were performed, but no significant difference was found. Finally, a funnel plot and Egger's regression test along with trim-and-fill analysis and fail-safe N were conducted to check for publication bias, but no significant bias was detected.
Conclusion: Smartphone-based mobile learning had significantly positive influence on nursing students' knowledge, skills, confidence in performance, and learning attitude. Smartphone-based mobile learning may be an alternative or supportive method for better education in nursing fields.

Introduction

Since 2010, when smartphone began to be widely used in Korea, it has become considerably influential in people's lives [1]. In 2016, the overall rate of smartphone use in Korea was about 90%; particularly among those in their 20s and 30s, the rate was high at 99% [2,3]. This indicates the young people's high level of access to smartphones [2,3]. A smartphone is a mobile device that is highly portable and accessible and can be used anywhere at any time. Thanks to smartphones, people can search for and provide information, cultural activities, learning tools, economic activities, and social communication more easily and faster [1,4]. A smartphone-based mobile education is used in various areas. Information can be replayed, and learners can work at their own pace; learning space is expanded owing to its high portability; simulation learning is also probable, using a user's location-based information; and a self-directed learning can be achieved, where students can practice certain target knowledge and skills repetitively without spatial restraints [4–6]. Specifically, smartphone-based mobile learning is believed to be appropriately applied to nursing education. With its high level of portability and accessibility, smartphone makes it possible to facilitate self-regulatory and active learning by motivating students and to promote collaboration and communication among students [4,7].

☆ Parts of the results were presented as a poster in the 21st EAFONS & 11th INC (21st East Asian Forum of Nursing Scholars & 11th International Nursing Conferences

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In the clinical settings where complex health care is required, nursing students experience many difficulties in applying the theoretical knowledge and trained skills that they have been taught at school to caring patients [8]. Moreover, although experienced students with advanced nursing skills are required in the clinical settings, nursing students have been offered less opportunities to apply their nursing knowledge and skills to patients in the current social context in which the safety and rights of patients become more important [9]. As a result, in many cases in nursing education, an educational intervention using mobile technology has been used as a supplementary tool for students to build up their clinical practice and experience [10], without any temporal and spatial restraints [11]. Using a mobile device, students can easily meet their diverse information needs for clinical practice and experience [12]. For example, a study reports on how prompt access to the medication and medical information using a mobile device enhances self-efficacy of students [11]. Moreover, competency is enhanced when the medication calculation exercise application is used through the cognitive load theory [13]. In addition, previous studies reported that when smartphone-based communication technologies [14] are applied to learn nursing skills, nursing competency is enhanced effectively [6,15,16].

Under the clinical settings where clinical guidelines are upgraded frequently, more emphasis is placed on monitoring the changing status of patients and providing accurate patient care. Therefore, using mobile devices is expected to have a positive impact on nursing education [10,17]. Phillippi and Wyatt [18] explained the usefulness of smartphone in nursing education as follows. By using a smartphone, prompt access to educational materials in the clinical setting is achievable; thereby checking the details before performing a certain task also becomes feasible [18]. Moreover, with a simulation-based learning that uses smartphone applications, the psychological burden of medical errors can be minimized, as there is no temporal and spatial restraints even under the situation where feedback for protégé cannot be communicated promptly; students can also be provided with an environment where self-directed learning can be achieved [18]. In other words, if the medication checking application is developed and harnessed, the safety of patients will be enhanced, and the self-confidence of nurses in their performance will be raised, as they can make right decisions [19]. As time spent on unnecessary work is reduced, nurses can spend more time on attending patients more carefully and enhancing the quality of care they provide. Nurses can also pursue the safety of patients as they do not have to leave the latter unattended while checking the necessary information with their smartphones [10].

Therefore, in nursing education, smartphone-based mobile learning has been applied mainly to nursing skill exercise and medication dosage calculation. The smartphone has become the educational tool preferred in nursing education for its advantages. For example, learning can be performed on demand without any temporal and spatial restraints; prompt access to accurate and latest information is viable; users are motivated to achieve self-directed learning; and an efficient communication between students and instructors is attainable [17]. However, despite such advantages and the necessity of smartphone-based mobile learning, only few studies [20,21] on nursing education have identified and evaluated the effects of smartphone-based learning systematically. Although O' Connor and Andrews in their study initially seemed to try conducting a systematic review and meta-analysis on the previous studies on using mobile devices for nursing education, they had difficulty in conducting a meta-analysis derived from including various types of mobile devices as their unit of analysis. Owing to this limitation, their piece of writing focused on the literature review of the previous studies but could not pursue a meta-analysis study [20]. Therefore, this study intends to systematically review the effects of smartphone-based mobile learning on the field of nursing and to provide the basic data for scientific research through a meta-analysis.

The purpose of this study is to confirm the general characteristics (study design, setting, sample size, intervention, outcome variables, and so on) of the selected studies, by examining systematically the previous studies that evaluated the effects of smartphone-based mobile learning on nursing education and to analyze the effects of smartphone-based mobile learning by presenting the effect size of the intervention through a meta-analysis.

Methods

Problem formation

A systematic review and meta-analysis was conducted to analyze and integrate the effects of smartphone-based mobile learning on nursing education for nurses and nursing students. This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis guideline [22], which is a representative research guide for systematic review and meta-analysis. To analyze the effect of smartphone-based mobile learning on nursing education, the selection criteria of studies included in this meta-analysis were searched according to PICO (population, intervention, comparison, and outcome).

1) Population (P): nursing students
2) Intervention (I): mobile learning by using smartphones
3) Comparison (C): other group or placebo group that does not receive mobile learning by using smartphones
4) Outcome (O): cognitive load, confidence in performance, knowledge, learning attitude, learning satisfaction, skill, and self-efficacy
5) Design (S): Randomized controlled trials or quasi-experimental study

In this study, meta-analysis including all types of mobile devices such as a personal devise assistant (PDA) and tablet computer in addition to a smartphone was performed at first. However, heterogeneity (high I^2 value) was large because of the wide variety of mobile devices. Therefore, in this study, only research using smartphones was analyzed.

In the present study, the exclusion factors were as follows: first, abstract or poster or the monographs and conference materials. Second, the article was not used in English. And the publication year of the article was not limited.

Search strategy and study selection

This study was carried out after obtaining the approval (Approval no. KHU IRB–17–007) from the institutional review board of Kyung Hee University to secure ethical validity for scientific research. For literature search for this study, we received help from a librarian who has more than 10 years of experience to select the search terms and the retrieval formulas because each database is different, and accordingly, the retrieval method is different. The search terms, such as nursing, students, education, and smartphone, were retrieved from each database after confirming the synonyms and related terms, including the Medical Subject Headings (MeSH) terms. Specific search terms and search expressions are as follows.

(1) “nurs* skill” OR “nurs* knowledge” OR “nurs* training” OR “nurs* learning” OR “informatic* nurs*” OR “nurs* study” OR

"nurs* teaching" OR "nurs* student" OR "nurs*" OR "pupil nurse" OR "student*" OR "undergraduate" OR "baccalaureate" OR "class*"(All Fields)

(2) "mobile* technology" OR "mobile* device" OR "mobile* app" OR "mobile* application" OR "mobile* computer" OR "portable computer" OR "portable* app" OR "hand held" OR "handheld" OR "handset" OR "PDA" OR "personal digital assistant" OR "smart phone" OR "smartphone" OR "iPhone" OR "tablet PC" OR "mobile learning" OR "M learning" OR "Mlearning" OR "wireless" OR "ICT" OR "information and communications technolog*"(All Fields)

(3) "education, nursing"(MeSH Terms) OR "nursing education"(Text Word) OR "nurs* education"(Text Word)

(4) (1) and (2) and (3)

According to assessment of multiple systematic reviews, a guideline for evaluating the quality of systematic review, at least two researchers should search for a systematic review [23]. Therefore, the electronic database search of this study was performed independently by two researchers, and peer-reviewed journals published by July 2017 were included for literature search. In addition to PubMed, Cochrane Library, and Embase, the retrieved electronic databases include Cumulative Index to Nursing and Allied Health Literature (CINAHL), Educational Resource Information Center (ERIC), ProQuest Cental, and SCOPUS. To search for gray literature, all references were reviewed and handsearched, and the year was not limited. A total of 3,419 documents retrieved through electronic databases and handsearching were moved to EndNote, one of the reference management databases. After removing 678 redundant data, 2,584 unrelated documents were removed through the title and abstract of the thesis. Thereafter, 63 no full-text articles were removed, and the full texts of the articles were reviewed according to the selection criteria and exclusion criteria. In this process, if the statistics for meta-analysis are not clearly presented in the article, mail was sent to the original author. After all the authors selected the search terms together, they independently searched the literature and screened the selected documents together. In case of disagreement, the whole data were reviewed together and consensus was made. Finally, 11 documents were systematically reviewed (Appendix 1). A total of 10 documents were meta-analyzed, except for one document in which the mean and standard deviation values were not obtained.

Quality assessment of the selected literature

The quality of the selected literature was assessed independently using Cochrane's risk of bias (ROB), with reference to a systematic review guidebook for Cochrane's intervention studies [24]. The ROB is composed of seven items as the quality evaluation method for the control experimental study, and the details are as follows: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias. Each item is rated low, high, or uncertain depending on the risk of bruising [24]. The inconsistent items went through a process of reconciliation through rigorous discussion and review of the original text.

Data analysis

In this study, we extracted the characteristics of selected research subjects and coded data according to the criteria analysis framework of coding. This is intended to serve as a basis for analyzing the heterogeneity of effect sizes, as well as a description of the properties of each study. The mean and standard deviation of the prescoring and postscoring scores of the two groups presented in each study were collected, and information on the sample size was collected. When the p and F values were presented, the effect size was calculated using the formula.

The size of the effect for each study was recognized by most studies that were not large in sample size, and the corrected standardized mean effect size, Hedges' g, was calculated, and a confidence interval (CI) of 95% and the weight of each effect were calculated using the inverse of the variance. Hedges' (g) was calculated by complementing Cohen's d because it is an effect size that compensates for the overestimated weakness when the sample size is small [25].

To analyze the effect size, "meta", a meta-analysis package of R program (R Foundation for Statistical Computing, Vienna, Austria), was used. The mean effect size was calculated by using a random-effects model assuming that the sample of each study, the intervention method, and the duration of the intervention were diverse [26]. To assess the statistical heterogeneity of the effect sizes, we visualized them through the forest plot and then calculated the I^2 value, which is the ratio of the interstudy variance. In general, when the I^2 value exceeds 50.0%, the degree of heterogeneity is interpreted as being significant [24]. To further explain the heterogeneity of the effect sizes shown in each study, we conducted subgroup analyses using meta-analysis of variance according to the characteristics of studies.

Finally, to verify the validity of the entire studies, publication bias was examined using funnel plot analysis. To confirm the statistical significance of asymmetry, Egger's regression test was performed on the relationship between the effect size and the standard error presented by Egger et al. [27]. In case of suspicion of publication errors, the method was reanalyzed by the trim-and-fill method of Duval and Tweedie [28] as a method of verifying the severity. This method removes nonsymmetric effect sizes from funnel plot analysis and then fills the left and right sides symmetrically around the pooled effect sizes [28]. The number of articles required to dismiss the results of the meta-analysis of the entire study was analyzed through fail-safe N (safety factor). Fail-safe N is a measure of the reliability of the results of meta-analysis. The magnitude of the effect size calculated from the published research is not significant due to unpublished results. The results of the fail-safe N show that the greater the number of required articles added, the more reliable the effect size calculated by the meta-analysis [24].

Results

Selection process

A total of 3,419 articles were retrieved from the literature search. There were 469 articles from PubMed, 15 articles from Cochrane Library, 223 articles from Embase, 1,933 articles from CINAHL, 36 articles from ERIC, 82 articles from Web of Science, 333 articles from ProQuest Central, and 323 articles from SCOPUS. There were also five gray documents retrieved from other sources. Among the 3,419 articles, 678 duplicates were excluded, and 157 were identified based on the title and abstract review. A total of 94 articles were fully reviewed by the researchers except for 63 articles without full text among 157 articles. Among them, 35 were not mobile learning, 25 were not intervention studies, 17 were single-group studies without a control group, and five did not report statistical results. A total of 11 articles were finally selected and among them, 10 articles were finally available for meta-analysis. The flow diagram of the study selection process is shown in Figure 1.

Descriptive summary of selected literature

Table 1 shows characteristics of the 11 studies. All of them were published in 2011, and eight studies (72.7%) were published in the last 3 years, from 2014 to 2017. Countries of where the studies were conducted were South Korea, Taiwan, China, Spain, and Colombia. More than half of the studies (six studies) were performed in South Korea. Research participants were nursing students (11 studies). Regarding the research design, two studies were randomized controlled trials, and nine were non-randomized controlled trials. The dependent variables that show effects of smartphone-based mobile learning were knowledge in six studies (1, 2, 5, 6, 9, and 10 of appendix 1], skills in seven studies [1, 4, 5, 6, 7, 8, and 10 of appendix 1], confidence in performance in three studies [5, 6, and 7 of appendix 1], learning attitude in two studies [8 and 10 of appendix 1], learning satisfaction in four studies [3, 4, 6, and 7 of appendix 1], cognitive load in two studies [8 and 10 of appendix 1], and self-efficacy in one study [four of appendix 1].

Evaluation of quality of the literature

In this study, the quality of the selected studies was assessed using Cochrane's ROB tool. Evaluation items included random sequence generation, allocation concealment, blinding of study participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias. Other sources of bias was evaluated based on the provider's expertise and delivery time of smartphone-based mobile learning.

Regarding the random sequence generation, 58.3% of the studies had low ROB, 33.4% had high ROB, and 8.3% had uncertain ROB due to a research method that was not presented in detail. In the allocation concealment, 41.7% had low ROB and 16.6%, uncertain ROB due to unclear description. Regarding the blinding of study participants and personnel, 33.3% had low ROB. In the blinding of outcome assessment, 83.3% had low ROB. In the incomplete outcome data and selective outcome reporting, 66.7% had low ROB. Regarding the other sources of bias, 83.4% had low ROB.

Effects of smartphone-based mobile learning

Among the 11 selected studies, nine were finally included for the meta-analysis. Figure 2 shows effects of smartphone-based mobile learning on nursing education. Forest plots were constructed for each outcome using the standardized mean effect size measured by the random effect model. Six outcomes were included in the meta-analysis: cognitive load, confidence in performance, knowledge, learning attitude, learning satisfaction, and skill. In general, smartphone-based mobile learning was shown as a significant intervention in nursing education; the total effect size of the intervention was g = 1.12 (95% CI: 0.72–1.52). The intervention lowered the cognitive load; however, group difference at

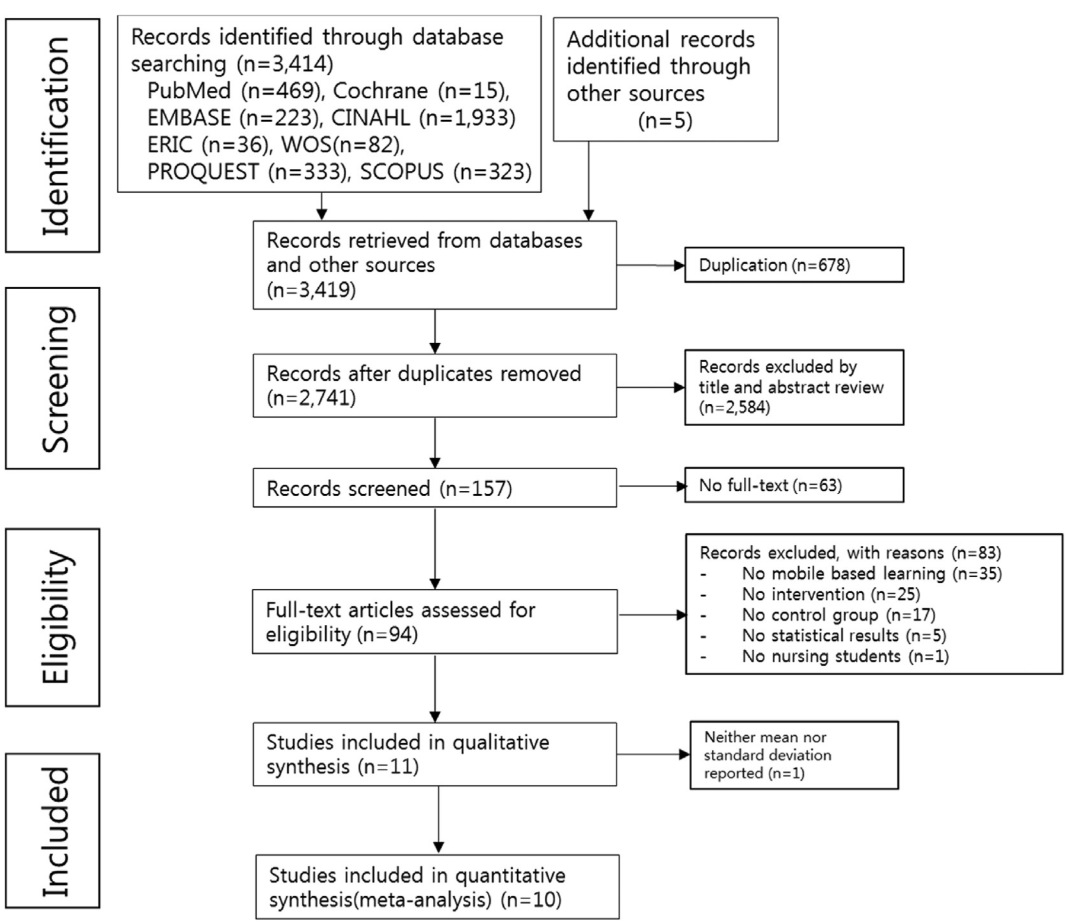

Figure 1. Flow diagram of study selection.

Table 1 *Descriptive Summary of Included Studies.*

No.	Author (year)	Country	Study design	Setting	Sample size Exp.(n)	Sample size Cont.(n)	Interventions Exp.	Interventions Cont.	Outcome variables	Main results
1	Choi et al. (2015) [A1]	Korea	NRCT	University	45	42	Communication course using a smartphone video clip	Theory lecture	Communication competence; Emotional intelligence	The experimental group improved more significantly than the control group in communication competence and emotional intelligence.
2	Gomez et al. (2016) [A2]	Colombia	NRCT	University	13	13	Mobile contextualized system	Traditional lecture	Academic performance	The experimental group reported a greater difference between pretest and post-test on academic performance than the control group.
3	Jeong (2017) [A3]	Korea	NRCT	University	39	37	Practice training using smartphone videos	General practice training	Nursing skill; Self-efficacy; Learning satisfaction	Smartphone video recording practice method had significant positive effects on the improvement of nursing skill and learning satisfaction.
4	Kim et al. (2012) [A4]	Korea	NRCT	University	37	41	Smartphone application for medication dosage calculation training	Paper-based handout	Self-efficacy; Anxiety; Calculation ability	The experimental group had higher self-efficacy and better medication dosage calculation ability than the control group.
5	Kim et al. (2017) [A5]	Korea	RCT	University	35	38	Smartphone-based app using video	Lecture-based education	Knowledge; Confidence in performance; Skill; Satisfaction with learning method	The smartphone-based education group showed significantly higher scores on skills and confidence in performance than the control group.
6	Lee & Shin (2016) [A6]	Korea	NRCT	University	29	29	Self-directed feedback practice using smartphone videos	Conventional practice	Basic nursing skill; confidence in performance; learning satisfaction	Basic nursing skill scores were higher in the experimental group compared with the control group.
7	Lee et al. (2016) [A7]	Korea	RCT	University	36	35	Mobile-based video clip	Conventional method	Learning motivation; fundamental nursing competency (knowledge, skill performance, and confidence in practice) class satisfaction	The intervention group showed significantly higher levels of learning motivation and course satisfaction. The intervention group was more confident in practice than the control group.
8	Li et al. (2017) [A8]	China	NRCT	University	202	184	Mobile learning application	Conventional method	Learning motivation; study performance	The students maintained a relatively high level of motivation for performing and had better study performance after practicing mobile learning.
9	Lin & Lin (2016) [A9]	Taiwan	NRCT	University	20	16	Integrated nursing training using mobile device (mobile interactive learning and diagnosis system)	Learning sheet	Learning achievement; cognitive load; learning attitude	The experimental results show that the proposed approach is helpful for students in improving learning performance and reducing cognitive loads.
10	Ortega et al. (2011) [A10]	Spain	NRCT	University	28	28	Mobile self-assessment	Conventional method	Achievement improvement	Results show that mobile self-assessment tool improves students' achievement.
11	Wu et al. (2012) [A11]	Taiwan	NRCT	University	22	24	Cognitive apprenticeship approach with the RFID-based mobile learning system	Traditional approach with learning sheet	Learning achievement (knowledge); skill test; cognitive load; learning attitude	The experimental results show that the students' learning outcome was notably improved by using the mobile learning system for nursing training.

Note. Cont. = control group; Exp. = experimental group; NRCT = nonrandomized clinical trial; RCT = randomized clinical trial; RFID = radio-frequency identification.

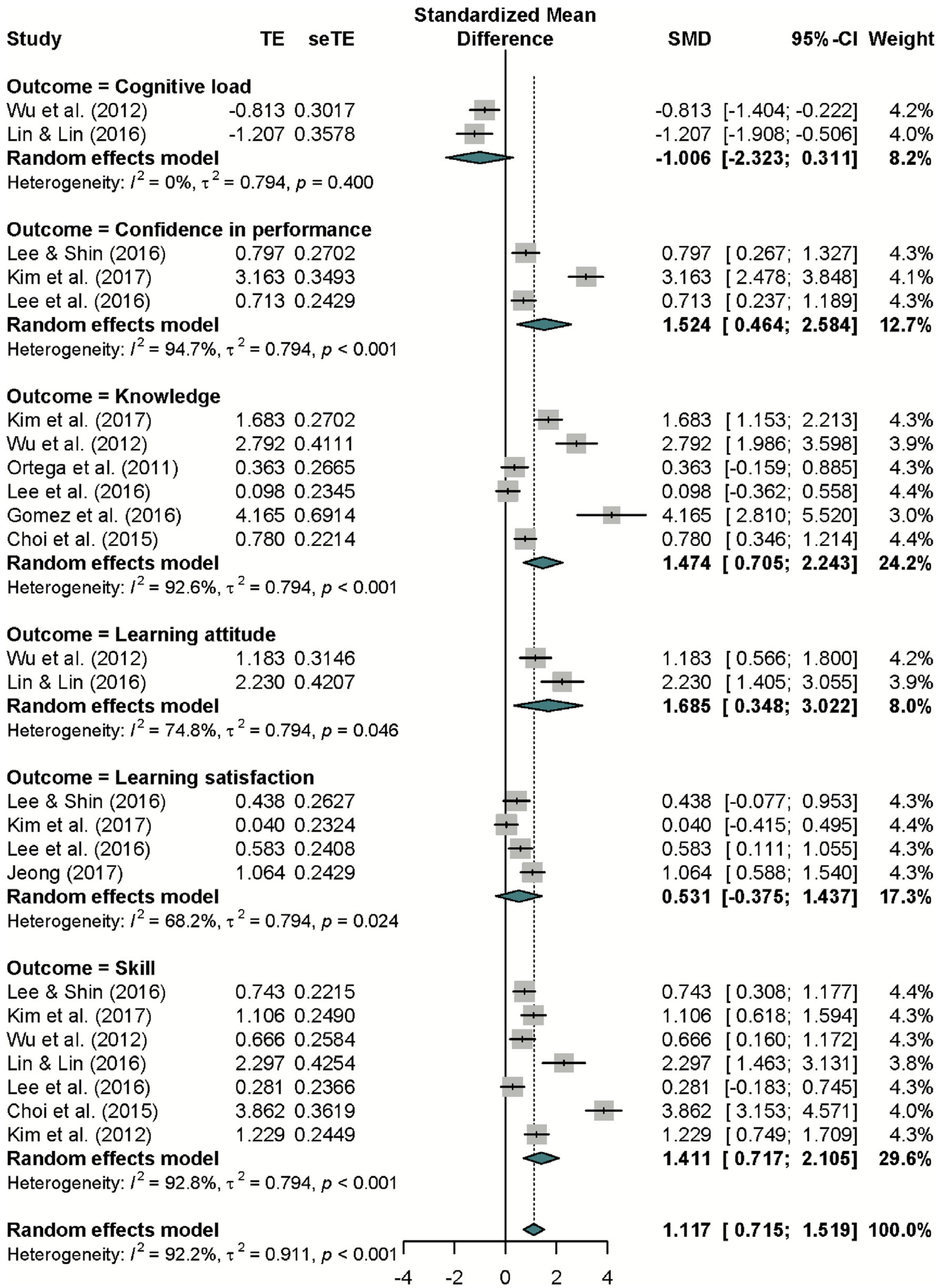

Figure 2. Effects of smartphone-based mobile learning in nursing education.
Note. CI = confidence interval; SMD = standardized mean difference.

postintervention was not statistically significant [g = −1.01 (95% CI: −2.32 ~ 0.31)]. At postintervention, there was a significant group difference in confidence in performance [g = 1.52 (95% CI: 0.46 ~ 2.58)]. There were seven studies which examined that the effect intervention on knowledge and group difference was significant and large at postintervention [g = 1.47 (95% CI: 0.71 ~ 2.24)]. Regarding learning attitude, there was a significant group difference at postintervention [g = 1.69 (95% CI: 0.35 to 3.02)]. At postintervention, there was no significant group difference in learning satisfaction [g = 0.53 (95% CI: −0.38 ~ 1.44)]. There were seven studies which examined that the effect intervention on skill and group difference was significant and large at postintervention [g = 1.41 (95% CI: 0.72 ~ 2.11)].

Homogeneity and subgroup analyses

Statistically significant heterogeneity was found in the overall effect size (I^2 = 92.2%, Q = 336.56, p < .001), confidence in performance (I^2 = 94.7%, Q = 75.31, p < .001), knowledge (I^2 = 92.6%, Q = 79.06, p < .001), learning attitude (I^2 = 74.8%, Q = 3.97, p = .046), learning satisfaction (I^2 = 68.2%, Q = 9.45, p = .024), and skill (I^2 = 92.8%, Q = 83.84, p < .001). Heterogeneity among the effect sizes of the cognitive load was neither important nor significant (I^2 = 0.0%, Q = 0.794, p = .400).

Therefore, exploratory explanations were needed for backgrounds with high heterogeneity of effect sizes among studies. Subgroup analyses using meta-analysis of variance were conducted according to the research design, subject type, intervention content, and sample size. Table 2 shows results of the subgroup analyses. The effect size of the randomized clinical trial group was 0.94 and that of the nonrandomized clinical trial (NRCT) group was 1.21. The effect size of the NRCT group was slightly higher than that of the NRCT group. However, the effect size was not statistically significant (Qb = 0.38, df = 1, p = .535). Regarding content related to intervention, the effect size of caring was 1.49, which was higher than those of fundamental nursing (g = 0.71) and medication (g = 1.23), but there was no statistically significant difference (Qb = 3.34, df = 2, p = .188). The effect size of the study group in Colombia (g = 4.17) was higher than those of the study groups in Korea (g = 1.08), in Taiwan (g = 0.98), and in Spain (g = 0.36), but there was no statistical significance (Qb = 7.39, df = 3, p = .060). The effect size of studies with a sample size less than 50 was 1.29, which was higher than the effect size of other studies with the sample size of 50 or more (g = 1.04); however, the effect size difference between the two groups was not statistically significant (Qb = 0.32, df = 1, p = .571).

Publication bias

Figure 3 presents results of the publication bias analysis through the funnel plot, which showed a slight asymmetry. Egger's regression test was also used to evaluate publication bias and concluded that asymmetry existed in the funnel plot (t = 3.08, df = 22, p = .005). Therefore, trim-and-fill method was also assessed for checking publication bias. After filling five effect sizes to the left of the funnel plot, the corrected total mean effect size (g) was 0.63 (95% CI: 0.17–1.09), which was still statistically significant. After conducting trim-and-fill method, Egger's regression test concluded that symmetry existed in the funnel plot (t = −0.01, df = 27, p = .993). The corrected total mean effect size was smaller than the overall mean effect size of 1.12 measured in 10 studies. In addition, the number of research required to reject results of the meta-analysis of this study was 2,258 according to the fail-safe N (stability coefficient).

Discussion

This study was conducted to examine the previous studies on the effects of smartphone-based mobile learning for nursing students systematically and to provide the basic data for an evidence-based nursing research by assessing the objective usefulness of the characteristics and effects of smartphone-based mobile learning through a meta-analysis.

Eleven studies which was carried out for the systematic review was carried out after 2011; 54.5% of them were conducted in Korea. This shows that smartphone-based mobile learning has been gaining attention since 2010, when smartphones started to be distributed widely. Moreover, it is an inevitable consequence that many of the studies were conducted in Korea, where the infrastructure for mobile learning had already been established and the rate of smartphone use by those in their 20s and 30s was at 99% in 2016 [3].

Although being excluded in this meta-analysis, only one study focused on nurses. The reason that most studies were conducted on nursing students rather than on nurses is that university students are more familiar with and adept at using smartphone applications and use smartphones more effectively [1] compared with nurses who work at hospitals. Nursing students also use smartphones relatively more freely and independently [4]. However, as the number of nurses who can search for information through mobile phones and are familiar with mobile services is increasing; further research must be conducted to identify the effects of smartphone-based mobile learning on nurses.

Most of the educational interventions included in this study contained relatively simpler and repetitive educational items such as exercising basic nursing skills, calculating medication dosage, and practicing communication. These items reflect the characteristics of mobile learning [29] with which users can find interesting and be motivated to pursue. By using mobile devices, users can be motivated to learn because they are familiar with the device and can learn anywhere at any time. Voluntary participation in learning has been proven to enhance the educational effect. In this systematic review, knowledge, skills, confidence in performance, cognitive load, learning attitude, and learning satisfaction were the

Table 2 *Subgroup Analyses by the Study Design, Subjects, Contents Related to Intervention, Country, and Sample Size.*

Category	Classification	k	Hedges'g	95% CI		I^2 (%)	Q_b (p)
				Lower	Upper		
Study design	RCT	8	0.94	0.24	1.64	91.6	0.38 (.535)
	NRCT	16	1.21	0.71	1.72	92.9	
Contents related to intervention	Caring	12	1.49	0.91	2.07	94.7	3.34 (.188)
	Fundamental nursing	11	0.71	0.12	1.30	85.3	
	Medication	1	1.23	−0.74	3.20	-	
Country	Korea	15	1.08	0.58	1.58	91.2	7.39 (.060)
	Columbia	1	4.17	2.81	5.52	-	
	Spain	1	0.36	−0.16	0.89	-	
	Taiwan	7	0.74	0.49	1.00	94.5	
Sample size	Smaller sample size (n < 50)	8	1.29	0.56	2.02	94.7	0.32 (.571)
	Larger sample size (n ≥ 50)	16	1.04	0.54	1.53	90.8	

Note. CI = confidence interval; k = number of outcomes; NRCT = nonrandomized controlled trial; Q_b = Q between groups; RCT = randomized controlled trial.

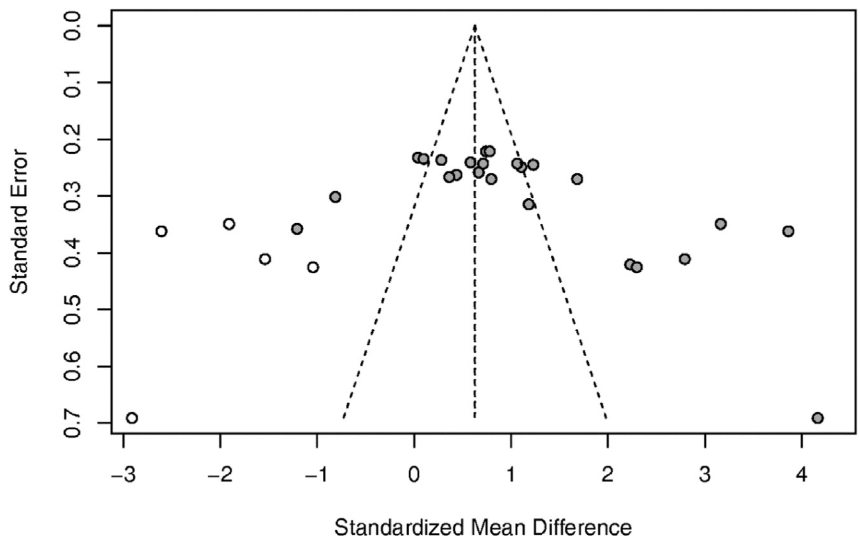

Figure 3. Funnel plots of standard error by standardized mean difference with five effect size estimates added by the Trim-and-fill analysis (open symbols).

outcome measures of smartphone-based mobile learning intervention studies.

In this study, the results of smartphone-based mobile learning consisted of seven studies that measured knowledge and skill, followed by only four studies evaluating confidence in performance and learning satisfaction and two studies checking learning attitudes and cognitive load. This is because the content of smartphone-based mobile learning is still mostly used as a supplementary means of face-to-face lectures [4]. They are used as a supplementary tool only for exercises relating to vocabulary learning or skill practice because of their technical limitations when used as a cognitive supplementary tool for supporting the thinking process of students [30]. Therefore, further research must be performed to create an experimental setting where various scientific technologies, including a virtual and an augmented reality, are combined.

In the present study, the relatively high ROB items in the quality assessment of the reviewed articles included random sequence generation, allocation concealment, and blinding of participants and personnel. There seemed to exist certain limitations of performing such items thoroughly when considering the characteristics of nursing research conducted on people as there were more quasi-experimental studies than randomized experimental ones. Therefore, to accurately determine the effect of smartphone-based mobile learning, we should try to reduce this bias. In addition, in this study, risk was lowered in the items of blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias. However, most previous studies did not provide the information on the period of intervention. Therefore, more attempts to correct this issue must be conducted in future research.

As a result of meta-analysis, there was an overall positive effect size for the outcome variables. They were observed to be significant in improving knowledge, skills, confidence in performance, and attitude toward learning but not in cognitive load and satisfaction with learning. Such results can be explained by using Kirkpatrick's four-step evaluation model [31]. The first step is students' reactions such as self-confidence; second, enhanced knowledge; third, behavioral changes such as improvement in skills; and fourth, the level of achievement. The previous studies analyzed in this study used smartphone-based mobile learning and found that such learning was effective in improving confidence in performance, attitude toward learning, and knowledge and skills. These areas correspond to the first, second, and third steps of Kirkpatrick's model. However, any significant effect on the cognitive load was not examined; this area corresponds to the fourth step, which refers to one's understanding of and adaptation to the quantity and quality of information.

This result is consistent with that of the study by Guo et al.'s [10], which found that the contents of mobile learning used in the healthcare area typically comprise simple items such as references, quizzes, and knowledge tests. These items have a low level of influence. This study also investigated the simple items such as repetitive skill practice and calculation of medication dosage and they are used as a supplementary tool for learning and do not show any higher level effect, including the cognitive load. O'Connor and Andrews [20], who performed a literature review on the effects of mobile learning in clinical nursing education, reported that education using a mobile device enhances knowledge and self-confidence of nursing students, and their productivity increases as they could quickly acquire available information. In this study, however, satisfaction with smartphone-based learning was not significant. This result could be because nursing students felt unfamiliar with smartphone-based mobile learning as a new teaching method. Similarly, Lahti et al. [21] also discussed that this issue of using unfamiliar new technology could be limited to raise learning satisfaction in their meta-analysis regarding the effects of e-learning in nursing education. Because the use of e-learning in nursing education had not been widely used, as a result, satisfaction with mobile learning was relatively lower than expected. Therefore, these issues must be considered in future research when planning and conducting an educational intervention that uses mobile devices.

It was observed that the research design, types of participants, intervention details, country of research, and number of samples were not statistically significant, confirming that factors other than these variables were applicable. Therefore, such variables, for example, intervention duration, must be considered in future research.

After conducting the Egger's regression test by revising the effect size through the trim-and-fill method to verify the publication bias and validity of study results, it was observed that the sample size became a bit smaller but did not have any statistical significance. It could be considered as insignificant bias even though the risk of publication bias cannot be totally ruled out. Moreover, it was concluded that the effects size calculated through the meta-analysis in this study had stability of the results based on the fail-safe N, which was calculated as large enough. This study presented various methodologies by suggesting the trim-and-fill method of Duval and Tweedie [28]. This method can perform additional analysis if a publication error is suspected, in addition to the traditional fail-safe N method.

The results of this study have the following limitations. It is likely that certain unpublished studies had been excluded as this study searched for and selected studies mostly in the eight databases for the systematic review and meta-analysis. Therefore, the measured effect sizes might have been different from the actual number to some extent. Moreover, most of the articles included in the meta-analysis were quasi-experimental studies. As there was a lack of details regarding the period during which mobile learning was provided, there were limitations in conducting a meta-analysis of the differences in effect size depending on the intervention period. Therefore, future research must analyze the differences in effect size depending on the period of the studies, the standardization of a randomized experimental study, and the intervention period.

Despite such limitations, the meta-analysis used in this study is a research method that can avoid unnecessary repetitive research and provide the evidence-based and reasonable data for clinical decision-making. In meta-analysis, individual study results can be integrated quantitatively and analyzed systematically, thereby the results can be generalized [25]. In this regard, this study is significant in that it provided an overview of and background on the development and application of smartphone-based mobile learning in nursing education. Through this study, guidelines are provided to avoid potential errors that can occur in planning a research on smartphone-based mobile learning in nursing education.

Conclusion

This study reviewed systematically 11 studies on smartphone-based mobile learning in nursing education that were conducted in Korea and in other countries and meta-analyzed 10 of them to analyze effect sizes. The results of this study revealed that smartphone-based mobile learning was effective in improving nursing students' attitude toward learning and had a positive impact on the order of learning knowledge, skills, and confidence in learning. Considering that the ratio of smartphone-based mobile learning has been increasing and is expected to continue to rise, this study is significant in that it calculated effect sizes of mobile learning. However, certain limitations in generalizing the intervention effect must be recognized, as most of the analyzed studies were quasi-experimental and not randomized trials. Therefore, future studies must conduct research pursuant to the randomized research guidelines.

Conflicts of interest

The authors declared no conflict of interest.

Appendix 1. Studies Included in Meta-Analysis

A1. Choi Y, Song E, Oh E. Effects of teaching communication skills using a video clip on a smart phone on communication competence and emotional intelligence in nursing students. Arch of Psychiatr Nurs. 2015; 29(2):90–5. https://doi.org/10.1016/j.apnu.2014.11.003

A2. Gómez JE, Huete JF, Hernandez VL. A contextualized system for supporting active learning. IEEE Trans Learn Tech. 2016; 9(2):196–202. https://doi.org/10.1109/TLT.2016.2531685

A3. Jeong H. Effects of nursing students' practices using smartphone videos on fundamental nursing skills, self-efficacy, and learning satisfaction in South Korea. Eurasia J Math Sci Technol Educ. 2017; 13(6):2351–65. https://doi.org/10.12973/eurasia.2017.01229a.

A4. Kim MS, Park JH, Park KY. Development and effectiveness of a drug dosage calculation traning program using cognitive loading theory based on smartphone application. J Korean Acad Nurs. 2012; 42(5):689–98. https://doi.org/10.4040/jkan.2012.42.5.689. Korean.

A5. Kim SJ, Shin H, Lee J, Kang S, Bartlett R. A smartphone application to educate undergraduate nursing students about providing care for infant airway obstruction. Nurse Educ Today. 2017; 48:145–52. https://doi.org/10.1016/j.nedt.2016.10.006

A6. Lee SG, Shin YH. Effects of self-directed feedback practice using smartphone videos on basic nursing skills, confidence in performance and learning satisfaction. J Korean Acad Nurs. 2016; 46(2):283–92. https://doi.org/10.4040/jkan.2016.46.2.283. Korean.

A7. Lee NJ, Chae SM, Kim H, Lee JH, Min HJ, Park DE. Mobile-based video learning outcomes in clinical: Nursing skill education a randomized controlled trial. Comput Inform Nurs. 2016; 34(1): 8–16. https://doi.org/10.1097/cin.0000000000000183

A8. Lin YT, Lin YC. Effects of mental process integrated nursing training using mobile device on students' cognitive load, learning attitudes, acceptance, and achievements. Comput Human Behav. 2016; 55:1213–21. https://doi.org/10.1016/j.chb.2015.03.076

A9. de Marcos Ortega L, Barchino Plata R, Jiménez Rodríguez ML, Hilera González JR, Martínez Herráiz JJ, Gutiérrez de Mesa JA, et al. Using M-learning on nursing courses to improve learning. Comput Inform Nurs. 2011; 29(5):311–7. https://doi.org/10.1097/NCN.0b013e3182285d2c

A10. Wu PH, Hwang GJ, Su LH, Huang YM. A context-aware mobile learning system for supporting cognitive apprenticeships in nursing skills training. Educ Technol Soc. 2012; 15(1):223–36.

References

1. Chang YO. The effects of smartphome addiction on university students on interpersonal competence and depression. Kor J Youth Stud. 2017;24(7):235–55. Korean.
2. Korea Information Society Development Institute (KISDISTAT). Possession of media device- mobile phone [Internet]. Seoul: KISDISTAT; 2017 [cited 2018 Jan 29]. Available from : https://stat.kisdi.re.kr/MediaPanel/MediaPanel.aspx?tablename=TBR_B_CELLPHONE
3. Gallup Korea. 2012-2016 Smartphone usage and smart watch [Internet]. Seoul: Korea Gallup; 2018 [cited 2017 Dec 12]. Available from : http://www.gallup.co.kr/gallupdb/reportContent.asp?seqNo=761
4. Kwon S, Lee JE. Development of prototype for a prototype of mobile learning with 3G mobile phone. J Lifelong Learn Soc. 2011;7(2):41–69. https://doi.org/10.26857/JLLS.2011.08.7.2.41. Korean.
5. Chen YS, Kao TC, Sheu JP. A mobile learning system for scaffolding bird watching learning. J Comput Assist Learn. 2003;19(3):347–59. https://doi.org/10.1046/j.0266-4909.2003.00036.x
6. Kim SJ, Shin H, Lee J, Kang S, Bartlett R. A smartphone application to educate undergraduate nursing students about providing care for infant airway obstruction. Nurse Educ Today. 2017;48:145–52. https://doi.org/10.1016/j.nedt.2016.10.006

7. Gómez JE, Huete JF, Hernandez VL. A contextualized system for supporting active learning. IEEE Trans Learn Tech. 2016;9(2):196–202. https://doi.org/10.1109/TLT.2016.2531685
8. Landers MG. The theory–practice gap in nursing: the role of the nurse teacher. J Adv Nurs. 2000;32(6):1550–6. https://doi.org/10.1046/j.1365-2648.2000.01605.x
9. Jeong H. Effects of nursing students' practices using smartphone videos on fundamental nursing skills, self-efficacy, and learning satisfaction in South Korea. Eurasia J Math Sci Technol Educ. 2017;13(6):2351–65. https://doi.org/10.12973/eurasia.2017.01229a
10. Guo P, Watts K, Wharrad H. An integrative review of the impact of mobile technologies used by healthcare professionals to support education and practice. Nurs Open. 2016;3(2):66–78. https://doi.org/10.1002/nop2.37
11. Greenfield S. Medication error reduction and the use of PDA technology. J Nurs Educ. 2007;46(3):127–31.
12. Farrell MJ, Rose L. Use of mobile handheld computers in clinical nursing education. J Nurs Educ. 2008;47(1):13–9. https://doi.org/10.3928/01484834-20080101-03
13. Kim MS, Park JH, Park KY. Development and effectiveness of a drug dosage calculation traning program using cognitive loading theory based on smartphone application. J Korean Acad Nurs. 2012;42(5):689–98. https://doi.org/10.4040/jkan.2012.42.5.689. Korean.
14. Choi Y, Song E, Oh E. Effects of teaching communication skills using a video clip on a smart phone on communication competence and emotional intelligence in nursing students. Arch Psychiatr Nurs. 2015;29(2):90–5. https://doi.org/10.1016/j.apnu.2014.11.003
15. Lee SG, Shin YH. Effects of self-directed feedback practice using smartphone videos on basic nursing skills, confidence in performance and learning satisfaction. J Korean Acad Nurs. 2016;46(2):283–92. https://doi.org/10.4040/jkan.2016.46.2.283. Korean.
16. Wu PH, Hwang GJ, Su LH, Huang YM. A context-aware mobile learning system for supporting cognitive apprenticeships in nursing skills training. J Educ Techno Soc. 2012;15(1):223–36.
17. Zayim N, Ozel D. Factors affecting nursing students' readiness and perceptions toward the use of mobile technologies for learning. Comput Inform Nurs. 2015;33(10):456–64. https://doi.org/10.1097/cin.0000000000000172
18. Phillippi JC, Wyatt TH. Smartphones in nursing education. Comput Inform Nurs. 2011;29(8):449–54. https://doi.org/10.1097/NCN.0b013e3181fc411f
19. Kim MS. Development and Effectiveness of smartphone application for the medication confirmation of high-alert medications. Korean J Adult Nurs. 2014;26(3):253–65. https://doi.org/10.7475/kjan.2014.26.3.253. Korean.
20. O' Connor S, Andrews T. Mobile technology and its use in clinical nursing education: a literature review. J Nurs Educ. 2015;54(3):137–44. https://doi.org/10.3928/01484834-20150218-01
21. Lahti M, Hätönen H, Välimäki M. Impact of e-learning on nurses' and student nurse knowledge, skills and satisfaction: a systematic review and meta-analysis. Int J Nurs Stud. 2014;51(1):136–49. https://doi.org/10.1016/j.ijnurstu.2012.12.017
22. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evauate health care interventions: explanation and elaboration. BMJ. 2009;339:b2700. https://doi.org/10.1136/bmj.b2700
23. Shea BJ, Grimshaw JM, Wells GA, Boers M, Andersson N, Hamel C, et al. Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. BMC Med Res Methodol. 2007;7:10. https://doi.org/10.1186/1471-2288-7-10
24. Higgins JP, Green S, editors. Cochrane handbook for systematic reviews of interventions [Internet]. Version 5.1.0. London, UK: The Cochrane Collaboration; 2011 [Cited 2011 March 20]. Available from: http://handbook.cochrane.org/
25. Hwang SD. Meta-analysis using. Seoul, Korea: Hakjisa; 2015. p. 11–192.
26. Cheung MW. A model for integrating Fixed-, Random-, and Mixed-effects meta-analysis into structural equation on modeling. Psychol Methods. 2008;13(3):182–202. https://doi.org/10.1037/a0013163
27. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315:629. https://doi.org/10.1136/bmj.315.7109.629
28. Duval S, Tweedie R. A nonparametric "trim and fill" method of accounting for publication bias in meta-analysis. J Am Stat Assoc. 2000;95(449):89–98. https://doi.org/10.2307/2669529
29. Strandell-Laine C, Stolt M, Leino-Kilpi H, Saarikoski M. Use of mobile devices in nursing student-nurse teacher cooperation during the clinical practicum: an integrative review. Nurse Educ Today. 2015;35(3):493–9. https://doi.org/10.1016/j.nedt.2014.10.007
30. Johansson PE, Petersson GI, Nilsson GC. Nursing students' experience of using a personal digital assistant in clinical practice- an interventional study. Nurse Educ Today. 2013;33(10):1246–51. https://doi.org/10.1016/j.nedt.2012.08.019
31. Kirkpatrick DL. Evaluating training programs: The four levels. 2nd ed. Oakland, CA: Berrett-Koehler Publishers; 1998. p. 229.