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Research Article

The effects of simulation-based education on medication administration knowledge and performance among nursing students

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Abstract

Background: Medication errors can lead to serious negative consequences. Meanwhile, reading theory books or listening to lectures away from the real environment may disrupt learning. Simulation-based learning using a virtual environment imitates real-world activities and engages learners in physical and practical activities. The aim of this study was to evaluate the effects of simulation-based education (SBE) on medication administration (MA) knowledge and performance among nursing students.

Methods: This quasi-experimental study was conducted in the 2018–2019 academic year using a pretest-posttest design and a control group. The subjects included 66 nursing students of the sixth semester of the Faculty of Nursing and Midwifery of Iran University of Medical Sciences (IUMS), Tehran, Iran. They were randomly allocated to the intervention (n = 36) and control (n = 30) groups. Subjects in the intervention group were trained through SBE in two-hour weekly sessions for four consecutive weeks, and their conterparts in the control group received only routine traditional training. The knowledge and performance were assessed using a researcher-made MA knowledge questionnaire and four MA performance checklists. Data were collected before, immediately after, and one month after the intervention and were analyzed using repeated measures analysis of variance as well as paired-samples *t test*, independent-samples *t*, Mann-Whitney *U*, Chi-square, and Fisher's exact test in SPSS software (v. 16.0).

Results: There were no significant differences between the groups before intervention ($P > 0.05$). The mean scores of MA knowledge and performance of the intervention group increased significantly after the intervention ($P < 0.05$).The mean scores of the intervention group were significantly higher than the control group in both post-tests ($P < 0.05$). The mean score of MA knowledge in the intervention group was 12.36±3.04 at pretest, 18.6±1.13 at the first posttest, and 18.7±1.2 at the second posttest. the mean score of MA knowledge in the control group was 12.43±2.41 at pretest, 12.66±2.39 at the first posttest, and 12.66±2.63 at the second posttest The mean scores of MA performance (Total) in the intervention group was 18.99±9.7, at the first posttest and 18.08±11.05 at the second posttest. And the mean scores of MA performance (Total) in the control group was 10.35±10.39, at the first posttest and 11.35±10.66 at the second posttest.

Conclusion: SBE is effective in improving nursing students' MA knowledge and performance. SBE is suggested to reduce medication errors among nursing students.

Keywords: Simulation, Medication error, Knowledge, Performance, Nursing students

Introduction

Medication therapy is a key component of successful patient management in clinical settings (1). Medication administration (MA) is among the most important and most complex responsibilities of nurses (2). The effectiveness of medications relies on accurate MA (3). Accurate MA needs adequate knowledge and skills regarding accurate medication preparation, patient education about medications, and evaluation of patient responses to medications (4). Medication error (ME) is a major challenge in medication therapy (5). By definition, ME is any preventable event which can be associated with inappropriate use of medication products or infliction of any injury to patient (6). There are different types of ME, including administration of a wrong medication, administration of a wrong dose, administration at a wrong time, administration of a wrong medication type, wrong preparation of medications, and errors in monitoring medication therapy (7). ME is among the most prevalent errors in healthcare settings (8). It is prevalent among physicians, nurses, pharmacists (9), and nursing students (10). A study reported that nurses are responsible for 28% of all MEs (11). ME increases healthcare costs and mortality rate, prolongs hospital stay, reduces patient trust in and satisfaction with healthcare services, and causes stress and ethical conflicts for healthcare providers (12).

Studies showed that more than half of the MEs are preventable through improving nurses' professional knowledge (13) , skills, and experience (14). In other words, an important contributing factor of ME by nurses is their lack of knowledge about accurate MA (15). Therefore, education can be a potentially effective strategy to prevent ME among nurses through improving their professional knowledge (16). A study reported that education has reduced ME incidence rate (5). Another study also showed that education improved nursing students' medication calculation and MA skills (17).

There are different educational strategies in nursing education, including lecture, group discussion, role playing, and simulation (18). Simulation-based education (SBE) is an interactive educational strategy in nursing education, in which learners actively engage in the process of learning through playing different roles in a simulated environment (19). It is an effective strategy to improve nursing students' clinical knowledge and skills and their engagement in the process of learning (20). Another study also reported the effectiveness of SBE on medication calculation and MA skills improvement among nursing students (21). Nonetheless, nursing instructors rarely use this strategy (22). A cumulative meta-analysis of outcomes of simulation-based education reports that among studies comparing SBE with non-simulation training, the effect was initially in favor of non-simulation training, but the addition of a subsequent study in 1997 made the combined effect slightly in favor of simulation, and by 2004 the effect was partially established. Evidence from replication assessment studies continues to show borderline statistical significance and wide confidence intervals in 2011. this study belived that some replication is necessary to obtain stable effect estimates and to explore different contexts (Cook, 2014). In addition, some nursing studies also show that SBE has not been given enough attention in nursing education and improving the performance of nursing students (23, 24).

Therefore, the present study was conducted to evaluate the effects of SBE on MA knowledge and performance among nursing students.

Methods

Design, setting and sample

This quasi-experimental study with a pretest-posttest design and a control group was conducted in the 2018–2019 academic year .

The study setting was the Faculty of Nursing and Midwifery of Iran University of Medical Sciences (IUMS), Tehran, Iran. The research population was all undergraduate nursing students of the sixth semester . All eligible students were recruited through census. The choice of sixth semester students was because the researchers' experience showed that nursing students perform poorly in drug management before entering the internship stage. In this study, one of the methods of drug administration (oral drug administration, injection through serum set or angioket, subcutaneous injection and intramuscular injection) was taught by the researcher. The eligibility criterion was agreement for participation and the exclusion criterion was any absence from the sessions of the study intervention. For educational purposes, the faculty's education department had already divided the six-semester

students into a group of 38 (Group A) and a group of 37 (Group B). Group A as the intervention group and Group B as the control group were selected by lot. Two students from group A and seven students from group B were excluded from the study due to various reasons including maternity leave, absence, transfer to other academic centers and academic suspension. In this way, 36 students were in the intervention group and 30 students were in the control group. In the follow-up phase, 6 students were removed from the intervention group (Figure 1). Finally, 30 students were placed in each group.

Instruments

The data were collected by a demographic questionnaire, a researcher-made MA knowledge questionnaire, and four MA performance checklists. Demographic questionnaire includes age, gender, clinical work experience, exam rank and average. The researcher-made MA knowledge questionnaire had twenty four-choice questions that were developed based on the existing literature on MA. Correct and incorrect answers were scored 1 and zero, respectively. Higher scores were indicative of greater MA knowledge. Three instructors from the study setting assessed and confirmed the content validity of this questionnaire. For reliability assessment, fifteen nursing students completed the questionnaire and the Kappa coefficient was calculated as 0. 84.

The four MA performance checklists included a 44-item oral MA checklist, a 67-item subcutaneous injection MA checklist, a 71-item intramuscular injection MA checklist, and a 26-item intravenous injection MA checklist, which were selected from the standard checklists for nursing procedures (25). The items were given a score of zero if they were not implemented and a score of one if they were implemented. , and were left blank if they were not applicable.. Higher checklist scores were indicative of better MA performance. The same three instructors who assessed the validity of the knowledge questionnaire assessed and confirmed the content validity of the checklists. To check the reliability of the measurement test Weighted Kappa's method was used. In this way, a questionnaire was given to 15 nursing students in the sixth semester who were eligible to enter the study. Data from these samples were not considered in the main study. Checklists were completed by two evaluators so that the kappa coefficient for the test to measure the knowledge of giving medicine was calculated as 0.84, and because it was higher than 0.80, the performance was evaluated as excellent.

Intervention

The study intervention was an SBE program that was implemented in two-hour weekly sessions for four consecutive weeks at the Nursing Clinical Skills Center of the Iranian School of Nursing and Midwifery, which was simulated to a hospital environment. To collect data, a pre-test was taken from both groups. . The second author provided participants in the intervention group with SBE about MA based on MA scenarios developed using the existing literature and guidelines (26). It was not done in the control group of the intervention, they received the routine training of their internship. The training was carried out for the intervention group for 4 weeks and one day each week for 2 hours after the completion of the internship, in the Nursing Clinical Skills Center of the Faculty of Nursing. It was simulated like a hospital environment. Necessary coordination was done with the education officials to ensure that the training sessions do not interfere with the internships. In the first session, the researcher gave explanations about the simulated environment. Then he taught in each session and based on the scenarios designed on the models available in the clinical skills center by the researcher one of the methods of drug administration (oral administration, injection through serum or angiocatheter, subcutaneous injection, and intramuscular injection). After the training in each session, the clinical scenario of drug administration related to the training in that session, which is prepared by the researcher using library studies and available resources, including books, magazines and reliable websites and researches conducted in relation to the current research. and adjusted. It was provided to the students in written form and the students were asked to give the patient's medicines to the patient based on the scenario. After that, the students practiced in groups of 5 based on the same scenarios. An example of the scenario was that the students were asked to give an injection to a patient who needs a intramuscular injection of a drug. Before the injection, the sensitivity of the drug should be checked and the injection should be done in the right area and in the right way. After practicing on the mollage, the students gave

explanations about their scenario and the researcher gave them feedback on their performance. Finally, the issues that needed to be corrected were identified and the relevant solutions were exchanged among all the students. At the end of the intervention and one month after the intervention, the post-test, which was the knowledge assessment test, was taken from the students of both groups. The performance of the students was also evaluated by the researcher with the checklists that were prepared from the nursing service standards checklist book, during the internship after the training and one month after the training.

Data analysis

The SPSS software (v. 16.0) was used to analyze the data. The measures of descriptive statistics (namely, mean, standard deviation, absolute frequency, and relative frequency) were used for data presentation. Within- and between-group comparisons were made using the repeated measures analysis of variance and the paired-samples t, independent-samples t, Mann-Whitney U, Chi-square, and Fisher's exact tests (A significance level of 0.05 was considered) .

Ethical considerations

The Ethics Committee of Iran University of Medical Sciences, Tehran, Iran, approved this study (code: IR.IUMS.REC.1397.1030). Necessary permissions for the study were obtained from the Research Administrations of Iran Faculty of Nursing and Midwifery and Iran University of Medical Sciences, Tehran, Iran. Participants were given clear information about the study aim and methods, data confidentiality, use of their data exclusively for the purposes of the present study, and honesty in data collection, analysis, and report. Written informed consent was obtained from all of them.

Results

Six participants from the intervention group were excluded due to their inability to attend the intervention sessions and final data analysis was performed on the data obtained from thirty participants in the control group and thirty participants in the intervention group.

The means of participants' age and total grade point average were 23.13±2.86 years and 17.04±0.86 in the control group and 22.68±3.77 years and 16.75±1.66 in the intervention group, respectively. Most participants in these groups were male (53.3% vs. 53.3%) and did not have clinical work experience (90% vs. 93.3%). Groups did not significantly differ from each other respecting participants' characteristics ($P > 0.05$; Table 1).

The mean score of MA knowledge in the intervention group was 12.36±3.04 at pretest, 18.6±1.13 at the first posttest, and 18.7±1.2 at the second posttest. The repeated measures analysis of variance revealed at least one significant difference among the measurement time points respecting the mean score of MA knowledge in this group. Pairwise comparisons showed that the pretest mean score of MA knowledge in this group was significantly less than both posttests mean scores ($P < 0.001$), while there was no significant difference between the posttest mean scores ($P = 0.999$). On the other hand, the mean score of MA knowledge in the control group was 12.43±2.41 at pretest, 12.66±2.39 at the first posttest, and 12.66±2.63 at the second posttest and the repeated measures analysis of variance revealed no significant difference among these three mean scores ($P = 0.823$). Between-group comparisons also indicated that while there was no significant between-group difference respecting the pretest mean score of MA knowledge ($P = 0.925$), both posttest mean scores in the intervention group were significantly greater than the control group ($P < 0.001$).

The mean scores of MA performance and its oral MA, subcutaneous injection MA, intramuscular injection MA, and intravenous injection MA were 181.99±9.7, 37.68±3.16, 59±3.67, 62.51±4.18, and 22.78±1.87 at the first posttest and 187.08±11.05, 38.37±3.88, 59.83±3.34, 65.47±4.31, and 23.4±22.2 at the second posttest, respectively. Within-group comparisons revealed that in the intervention group, the mean scores of MA performance and its subcutaneous injection MA, intramuscular injection MA, and intravenous injection MA significantly increased ($P < 0.05$) and the mean score of oral MA did not significantly change ($P = 0.103$). In the control group, the mean scores of MA performance and its oral MA, subcutaneous injection MA, intramuscular injection MA, and intravenous injection MA were respectively 107.35±10.39, 22.5±4.16, 34.75±5.17, 37.99±4.29, and 12.09±2.28 at the first posttest and 111.35±10.66, 22.74±3.85, 36.61±4.67, 38.87±4.87,

and 13.12±2.03 at the second posttest. Within-group comparisons in the control group showed significant increase in the mean scores of subcutaneous injection MA and intravenous injection MA ($P < 0.05$) and insignificant change in the mean scores of total MA performance, intramuscular injection MA, and oral MA ($P > 0.05$). Between-group comparisons also revealed that the mean scores of MA performance and all its dimensions in the intervention group were significantly greater than the control group at both posttests ($P < 0.01$).

Table 1. Between-group comparisons respecting participant's characteristics

Characteristics \ Group		Control M±SD/N(%)	Intervention M±SD/N(%)	*P* value *
Age (Years)		23.13±2.86	22.68±3.77	0.643 *
Total grade point average		17.0±04.86	16.1±75.66	0.411 *
Gender	Male	16 (53.3)	16 (53.3)	0.833 **
	Female	14(46.7)	14(46.7)	
Clinical work experience	Yes	3(10)	2(6.7)	0.999 **
	No	27(90)	28(93.3)	

*T-test and ** K2

Table 2. Within- and between-group comparisons respecting the mean scores of medication administration knowledge and performance

Medication administration	Time Group	Before	Immediately after	One month after	P value*	P value**
Knowledge	Control	12.2±43.41	12.2±66.39	12.2±66.63	0.823	< 0.001
	Intervention	12.3 ± 36.04	18.1 ± 6.13	18.1 ± 7.2	0.001	
	P value^	0.925	< 0.001	< 0.001	------	
Performance (Oral)	Control	—	22.5±4.16	22.74±3.85	0.746	< 0.001
	Intervention	—	37.68 ± 3.16	38.37 ± 3.88	0.103	
	P value^	—	< 0.001	< 0.001	------	
Performance (subcutaneous injection)	Control	—	34.75±5.17	36.61±4.67	0.042	< 0.001
	Intervention	—	59±3.67	59.83±3.34	0.049	
	P value^	—	< 0.001	< 0.001	------	
Performance (intravenous injection)	Control	—	12.09±2.28	13.12±2.03	0.001	< 0.001
	Intervention	—	22.78±1.87	23.4±22.2	0.018	
	P value^	—	< 0.001	< 0.001	------	
Performance (intramuscular injection)	Control	—	37.99±4.29	38.87±4.87	0.176	< 0.001
	Intervention	—	62.51±4.18	65.47±4.31	0.001	
	P value^	—	< 0.001	< 0.001	------	
Performance (Total)	Control	—	10.35±10.39	11.35±10.66	0.058	< 0.001
	Intervention	—	18.99±9.7	18.08±11.05	0.001	
	P value^	—	< 0.001	< 0.001	------	

^: The results of the independent-samples *t* test; *: The results of the paired-samples *t* test; **: The results of the repeated measures analysis of variance

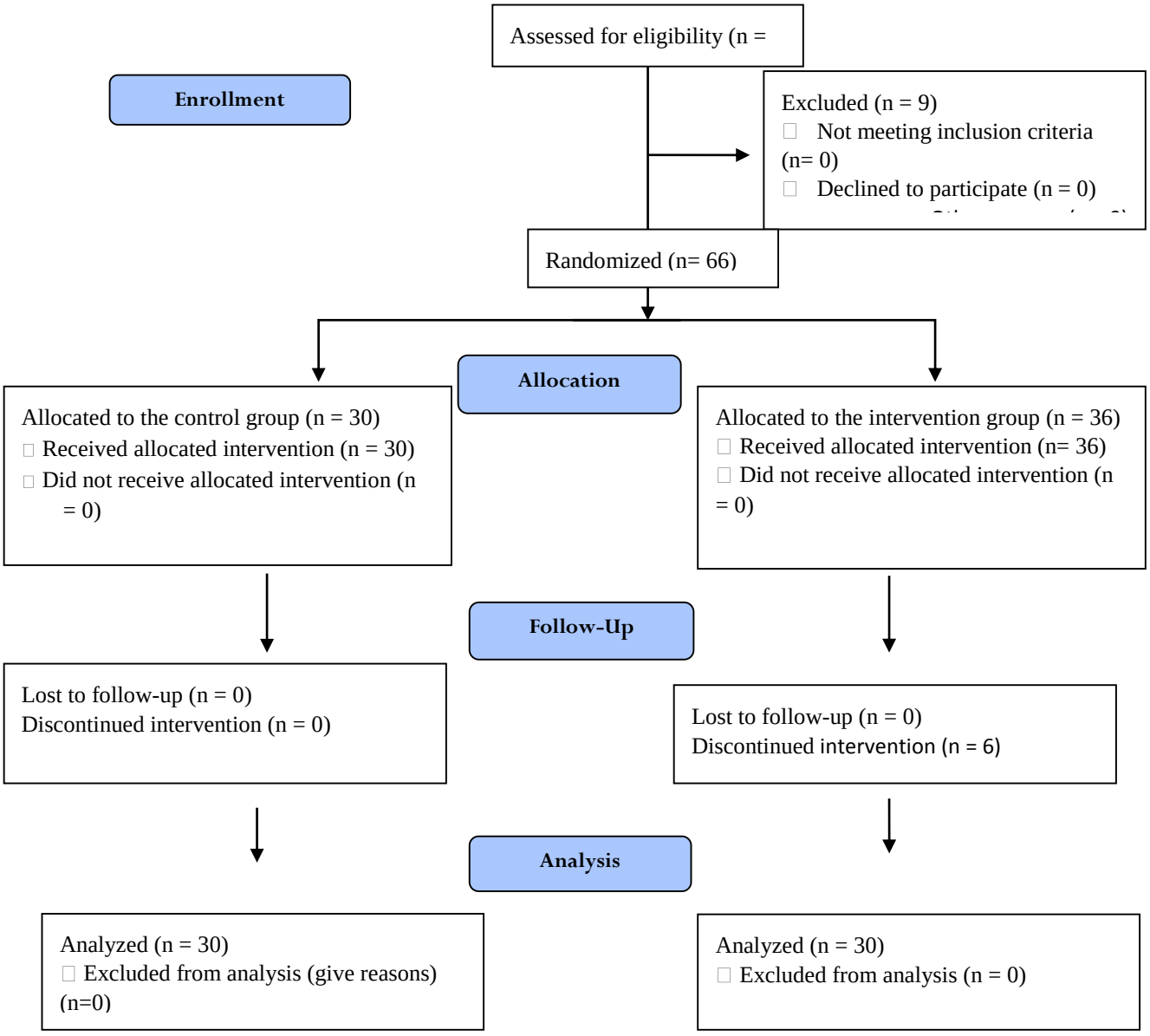

Figure 1. The flow diagram of the study

Discussion

The aim of this study was to evaluate the effects of SBE on MA knowledge and performance among nursing students. Findings showed the significant positive effects of SBE on nursing students' MA knowledge. In agreement with our findings, three previous studies reported that SBE significantly improved nurses' and nursing students' professional knowledge (27-29). The results of Chang et al.,'s study (2022) showed that the educational program based on virtual simulation has an effect on the belief and self-efficacy of nursing students (30). The significant positive effects of SBE are attributable to the fact that SBE actively involves learners in the process of learning (28, 31, 32). However, contrary to our findings, a study showed that SBE about cardiopulmonary resuscitation had no significant effects on medical students' resuscitation-related knowledge (33). This contradiction may be due to the differences between the studies with respect to their interventions and their participants' characteristics. Also, this result can be related to the duration of training, evaluation methods, and tools used.

We also found insignificant change in the mean score of knowledge in the control group. The effectiveness of traditional methods on the learning of nursing students is limited (34) and highlights the importance of revising the nursing curriculum based on innovative educational strategies (35-38). Traditional educational strategies do not provide learners with ample opportunity to think and reflect (39). Therefore, educational strategies which actively involve learners in the process of learning, improve their problem solving, and provide them with the opportunity to use their knowledge in real environment are necessary (39, 40). It is noteworthy that nurses' and nursing students' limited MA knowledge may lead to ME (41-43) and reduce their ability to accurately perform nursing procedures (44).

Study findings also revealed that SBE significantly improved MA performance, while traditional educational strategies in the control group had no significant effects on students' MA performance. In agreement with our findings, a study indicated that SBE significantly improved nurses' performance and reduced their ME (45). Another study found that SBE significantly improved nursing students' medication calculation and MA skills (46). Moreover, a study reported that SBE in nursing promotes learning and develops nursing students' skills and performance (47). Two other studies reported SBE as an effective strategy to develop professional skills and clinical performance among nursing students and healthcare providers (27, 48). An explanation for the positive effects of SBE on performance is that it provides learners with a real-like environment so that the knowledge acquired through it can be generalized to real environments (49). Moreover, it provides learners with the opportunity to safely perform different roles (50) and procedures and actively perform and develop their critical thinking and clinical skills through repeatedly exercising them in a safe real-like environment through trial and error without experiencing or inflicting any damage (50-54). Thus, it improves their self-confidence and mastery in clinical skills, reduces their anxiety (50, 52, 54), and enables them to show appropriate behaviors and practice in real clinical environment (51, 53). Another explanation for the positive effects of SBE on students' performance is that it empowers them to use their educational, perceptual, and mental experiences and improves their thinking, evaluation, problem-solving, decision making, and data analysis skills (52). In other words, SBE provides students with the opportunity to think about their performance, select and use the most appropriate solutions, prevent potential errors in their future practice (55), and link theory to real practice (56). Our findings also showed that SBE had long-term effects on MA knowledge and performance which lasted for at least one month. Based on the results of the study of Alshutwi et al.,2022, SBL is a valuable educational strategy that significantly increases the self-awareness, self-confidence, clinical performance, and efficiency of nursing students (57).Another study found the long-term effects of SBE on resuscitation-related knowledge (58). Moreover, a study showed that the effects of SBE lasted at least for three months (59) and a study reported that SBE had higher learning retention rate than other educational strategies and can be used to improve most clinical skills of nursing students (52). The high learning retention rate of SBE can significantly reduce ME rate over time (45). The long-term effects of SBE are attributable to its significant positive effects on critical thinking (60, 61), clinical judgment (62), and learners' involvement in the process of learning (63, 64). Learners' active involvement in the process of learning provides them

with the opportunities to interact with others, work on common goals, exchange their ideas, get familiar with new feelings and ideas, understand their personal differences, understand the need for help and learning in themselves and others, and attempt to promote their learning, which eventually promote their long-term learning (Goris, Bilgi & Bayindir, 2014). However, we found that SBE had no significant long-term effects on oral MA performance of nursing students. It is concluded that the effect of educational methods is not stable, and this issue requires continuous education and learning. In any case, SBE has a significant effect on the learning and performance of nursing students compared to traditional approaches.

Limitations

Among the limitations of the present study were the possibility of between-group information leakage, the effects of observer's presence on performance test, and the short follow-up period of the study. Therefore, studies with longer follow-up periods are recommended to determine the long-term effects of SBE on knowledge and performance respecting the different types of MA such as MA through nasogastric tube, topical MA, and inhaled MA.

Conclusion

This study concludes the significant positive effects of SBE in significantly improving MA knowledge and performance among nursing students. Educational effects following the SBE method have a longer duration than traditional methods. Therefore, SBE can be used to improve nursing students' knowledge and performance respecting MA. It is recommended to use the findings of this study to apply SBE in teaching nursing students, also, it is recommended to design and implement more practical research according to the results of this study.

Authorship

Conceptualization and methodology: Alice Khachian and Mina pahlavan; Data collection: Mina pahlavan, Mohammad Hosseini; Writing-review & editing, and funding acquisition and resources: Alice Khachian, Mina pahlavan; Writing--original draft: Mina pahlavan, Alice Khachian ; statistical analysis: Hamid haghani;

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Conflict of interests

The authors declared no conflicts of interests

Author's contribution: Conceptualization and methodology: Alice Khachian and Mina pahlavan; Data collection: Mina pahlavan, Mohammad Hosseini; Writing-review & editing, and funding acquisition and resources: Alice Khachian, Mina pahlavan; Writing--original draft: Mina pahlavan, Alice Khachian ; statistical analysis: Hamid haghani; Approval of final manuscript: All the authors.

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