Original Research Article

"The efficacy of high-fidelity simulation-based education in enhancing knowledge among undergraduate medical students"

ABSTRACT

Background: Medical education has experienced important changes in recent times. The concern for patient's safety is one of the key reasons for the change in medical curricula. Innovative instructional methods like simulation-based medical education (SBME) has evolved to address this problem. SBME has become an essential part of education and training for health professionals in many parts of the world. There are evidences that support that high-fidelity simulation (HPS) training has enhanced clinical knowledge among medical students.

Aims: The objective of this study was to note the differences in the knowledge made by high-fidelity simulation-based medical education among undergraduate medical education.

Study design: It was a quasi-experimental time series study with Pre-test and Post-test interventions.

Place and Duration of Study: Clinical Skills Lab, Faculty of Medicine, Manipal University College Malaysia, Melaka, between October 2015 and September 2017.

Methodology: The study involved 347 final year undergraduate medical students. The participants were divided into groups during the simulation sessions and their knowledge was assessed individually with Multiple Choice Questions (MCQ) and also self-reported Pre-test and Post-tests. Paired t-test was used to determine the difference of MCQ scores between pre and post simulation sessions. One-way repeated measure ANOVA was performed to determine the significant difference in knowledge assessment of self-reported Pre-test and Post-test scores. P value < .001 was taken to be of statistical significance.

Results: Post-test MCQ scores were higher than Pre-test scores but not statistically significant (P = .013). The total scores of the self-reported knowledge tests were significantly increased over time (P < .001).

Conclusion: There is enhancement of knowledge as perceived by the students with self-reported knowledge tests but not statistically significant as revealed by the MCQ scores.

Keywords: Hi-fidelity simulation, simulation-based medical education, undergraduate medical education, knowledge in simulation, efficacy in simulation, Pre-test and Post-test, experiential learning.

1. INTRODUCTION

Healthcare simulation is now routinely used for training of medical students and professionals in many academic institutions due to the increased awareness of patient safety and its standing on healthcare accountability. The great advances in the simulation technology has benefitted in this regard [1, 2]. Simulation has been used extensively for a long time in some high-risk professions like training pilots in aviation industry although it is relatively new in healthcare. Any learning activity that employs simulation technology to replicate clinical scenarios can be termed simulation-based medical education (SBME). It allows learners to make mistakes and learn from them without the fear of real harm to the patients [3]. Medical simulation has shown that adequately trained medical graduates would make less life-threatening mistakes and costly medical errors [4, 5]. The technological advancements of the simulation devices along with the research in healthcare simulation in the last two decades have encouraged the implementation of simulation-based medical education (SBME) in the medical field [6]. High-fidelity patient simulators as part of the SBME provides great opportunities to medical students for early exposure to the clinical environment by imitating real-life clinical scenarios and learning their management in a safe environment [7]. These guided and interactive experiences simulate real clinical settings that vastly support students' understanding of the relevant topics [8, 9]. The application of case-based scenarios during HFS sessions may complement clinical practice and knowledge retention. A study by Alanzi et al (2017) demonstrates that SBME significantly improves knowledge, skills and self-confidence [10]. All these advantages of SBME makes it an unique teaching modality that researchers have been exploring for enhancing the learning of the medical students [6]. Medical students could not retain a considerable proportion of their knowledge for extended periods of time and consequently HPS-based education may be supplemented with clinical experiences for enhancing and retention of knowledge [8]. HFS-based education has proven effective as a learning tool for technical and non-technical skills but its usefulness in acquisition of knowledge is yet to be validated [11]. The importance of HFS in training medical students has been recognized by academic institutions around the world but few studies have been designed with the principal objective of exploring the effectiveness of HFS-based education in acquisition of knowledge in the setting of surgical emergencies. In this background the main aim of our study was to observe the efficacy of HPS-based education in acquisition and retention of knowledge among the undergraduate medical students.

2. METHODOLOGY

Type of study: Quasi-experimental time series design study with Pre-test and Post-test interventions. This study was the extension of our preliminary research with the addition of MCQ for determination in the improvement of knowledge and some modifications in the methodology [12].

Eligibility criteria for the participants: Both male and female undergraduate (MBBS) final year students of Manipal University College Malaysia (MUCM), formerly known as Melaka-Manipal Medical College (MMMC) were recruited. Informed consent was taken from all the participants.

Exclusion criteria: Students who had not consented to participate in this study.

Sample size: G*Power 3.1 analyses showed that a sample size of 340 participants was required for establishing a moderate effect size of 0.25 on a F-test with a power of 0.90 for one-way repeated measure ANOVA [13].

Study area: Clinical Skills and Simulation Lab of Manipal University College Malaysia (MUCM), Melaka.

Study period: October 2015 to September 2017.

Intervention: Adult High-Fidelity Simulator (HFS) with modelled physiology known as METIman Pre-Hospital (Serial number: MMP-0418; CAE Healthcare, USA) was used for the study.

Outcome tool for measurement of knowledge: There were two components of knowledge assessment – self reported knowledge scores based on a questionnaire as perceived by the students (see Table 1) and MCQ scores (Pre-test and Post-test). An identical set of single-best answer A-type MCQs were used for both Pre-test and Post-test MCQ assessments. The questionnaire and the MCQs were constructed based on the teaching sessions to assess their learning outcome. The self-reported assessments were administered four times (Pre-test, Post-test I, Post-test II and Post-test III). The Pre-test for both self-reported and MCQ assessment were administered just before the first HFS session on the same day. The self-reported Post-tests were taken by the participants immediately after each HFS session. The participants took the Post-test MCQ immediately after the last HFS session along with the feedback assessment.

A pilot study was conducted prior to the main study that involved 50 students to explore the time management, feasibility, acceptability and validation of the self-reported questionnaires and MCQ.

A group of 12 to 15 participants were enrolled for each session. They were further divided into three teams of 4 to 5 students each to participate in the study. Informed consent was obtained from the participants who volunteered to take part in the study on the first day. After the consent was obtained, the participants were briefed on the study protocol, learning objectives, simulation sessions and expected learning outcomes. The research team adopted the principles of the Advanced Trauma Life Support Manual [ATLS®]: The Ninth Edition, developed by the American College of Surgeons (ATLS, 2013) as the standardized protocol for the management of surgical emergencies for our study [14]. During the briefing process, the participants were explained about the confidentiality of the HFS sessions and the ethical issues involved. They were informed about the environment of the clinical skills lab and the functions of the high-fidelity simulator to mitigate the undue stress caused by unfamiliar settings of the simulation sessions. The students were assured that the study outcome was not part of the evaluation process for the curriculum.

The briefing was followed by the first knowledge assessment (Pre-test) for all the participants. A self-reported questionnaire along with MCQ was used for evaluation of participant' baseline knowledge on the management of surgical emergencies following the principles of ATLS manual. All the students were taught the module for the management of surgical emergencies following the ATLS protocol before they participated for this study. The self-reported knowledge questionnaire for both Pre-test and Post-tests were identical. It contained four items that were used to compare the progress in knowledge as perceived by the participants. An ordinal scale (1 to 5) was used to rate the self-assessment scores as described below (Table 1).

Table 1: Self-reported knowledge questionnaire for Pre-test, Post-test I, Post-test II and Post-test III assessments.

Knowledge Assessment Item		Tick the column that you think most appropriate				
		No knowledge (1)	Poor knowledge (2)	Average knowledge (3)	Good knowledge (4)	Excellent knowledge (5)
1.	ATLS protocol for management of acute trauma					
2.	The management of Hypovolemic Shock					
3.	The management of Tension Pneumothorax					
4.	The management of Head Injury					
Remarks:						

The self-reported knowledge questionnaire was developed by our faculty based on the principle of Modified Simulation Evaluation Test [15]. The validation of the questionnaire was done by six experts in the field of medical education after reviewing the items and rated them on their suitability, clarity, and relevance. The questionnaire were then administered to 50 final year medical students who participated in the pilot study. It was finalized for application in the main study following the feedback from the pilot study. Cronbach's alpha coefficient of the questionnaire was calculated for internal consistency which came out to be 0.872. The students who had participated in the pilot study were excluded from the main study.

Apart from the self-reported knowledge questionnaire, identical MCQs were also used for the assessment of knowledge as Pre-test and Post-test. It comprised of 10 MCQs that were to be completed in 10 minutes. The single-best answer A-type MCQs with five options as answers were constructed following the guidelines framed by the National Board of Medical Examiners [16]. For each correct response, a score of one point was awarded. No negative marking was awarded for incorrect response. Based on the learning objectives, the MCQs were constructed by 6 experts in the field of Medical Education who were not part of this research study. The MCQs covered the items on ATLS protocol, and assessed for knowledge comprehension and knowledge application. The difficulty index for item difficulty as well as bi-serial correlation for item discrimination of each MCQ was analysed. The value between 30 and 95 in difficulty index and the bi-serial correlation value more than 0.2 were taken as the accepted standard in the study. The MCQ answer sheets were scanned by Konica Minolta FM (172.17.5.12) scanner and graded by using Optical Mark Recognition (OMR) software (Remark Office OMR, version 9.5, 2014; Gravic Inc., USA).

All the three teams in a particular group then participated in the first simulation session. The time allocated for each simulation session was as follows: Pre-brief (10 minutes), Simulation (20 minutes) and Debriefing (20 minutes). The same teams then participated in the second simulation session after 1 week and in the third simulation session after 3-4 weeks' time from the second simulation session. Standardized identical HFS scenarios were used for all the teams. The HFS scenarios were constructed by the investigators after arriving at a consensus following detailed discussion. These scenarios were first applied in the pilot study. They were finalized for application in the main study after reviewing the feedback from the pilot study. The individual student's perception of enhancement and retention of knowledge in the short-term to medium-term was assessed by using the validated self-reported questionnaires (Post-tests) after completion of each HFS session. Thus, the participants' perception of knowledge acquisition was assessed four times (Pre-test, Post-test I, Post-test II and Post-test III). The MCQs were used twice (Pre-test and Post-test) for assessing the progression of the participants' knowledge. The Pre-tests for the self-reported questionnaire and the MCQ were conducted on the first day of the course for all the participants. Post-test MCQ and Post-test III self-assessment questionnaire were administered on the last day of the course.

Data Analysis: SPSS software (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc.) was used for data analysis. Median, 1st quartile (Q1) and 3rd quartile (Q3) were calculated for each individual item in knowledge assessments. For determination of significant difference in total scores of knowledge assessments, the one-way repeated measure ANOVA with Bonferroni post-hoc analysis was applied. Friedman test was used for determination of significant difference in individual items of knowledge assessments. Normality was checked for quantitative continuous variables using skewness, kurtosis, and Q-Q plot. Paired t-test was calculated to determine the difference of MCQ scores between Pre-test and Post-test knowledge assessment. P value < 0.001 was considered to be statistically significant.

3. RESULTS

The total number of students eligible for the study was 375. 2 students declined to participate in the study (Table 2).

Table 2: Study population.

Number of students eligible for the study	375	
Number of students declined to participate	2	0.53%
Number of students enrolled for the study	373	99.47%
Number of students dropped out from the study	26	6.97%
Number of students completed the study	347	93.03%

A one-way repeated measured ANOVA with Bonferroni post hoc analysis was conducted to determine whether there was a statistically significant difference in knowledge assessment over time during simulation course. Mauchly's test of sphericity indicated that the assumption of sphericity had been violated, $\chi^2(5) = 80.492$, $p < 0.001$. Greenhouse & Geisser was used to correct the one-way repeated measures ANOVA. The total score of self-reported knowledge assessment was significantly increased over time, $F(2.48, 679.79) = 257.52$, $p < 0.001$, as shown below (Table 3).

Table 3: Total score of self-reported knowledge assessment at Pre-test, Post-test I, Post-test II and Post-test III.

Assessment **(One-way repeated measure ANOVA)**	**Total score of Knowledge Assessment** Mean (SD)	***P* value**
Pre-test	7.99 (3.28)	< .001*
Post-test I	11.66 (2.92)	
Post-test II	12.52 (2.89)	
Post-test III	13.33 (2.84)	
* Significant		

In the unpaired t-test, the Pre-test and the Post-test MCQ scores were normally distributed as assessed by skewness, kurtosis and Q-Q plot. Post-test MCQ scores were higher than Pre-test MCQ scores but not statistically significant (*P* value = .013) as shown below (Table 4).

Table 4: Comparison of Pre-test and Post-test MCQ scores (unpaired t-test).

Unpaired t-test			
Variable	**MCQ scores**	**Mean difference (95% confidence**	

	Mean (SD)	interval)	*P* value
Pre-test	4.61 (1.50)	0.28 (0.06, 0.50)	.013
Post-test	4.89 (1.62)		

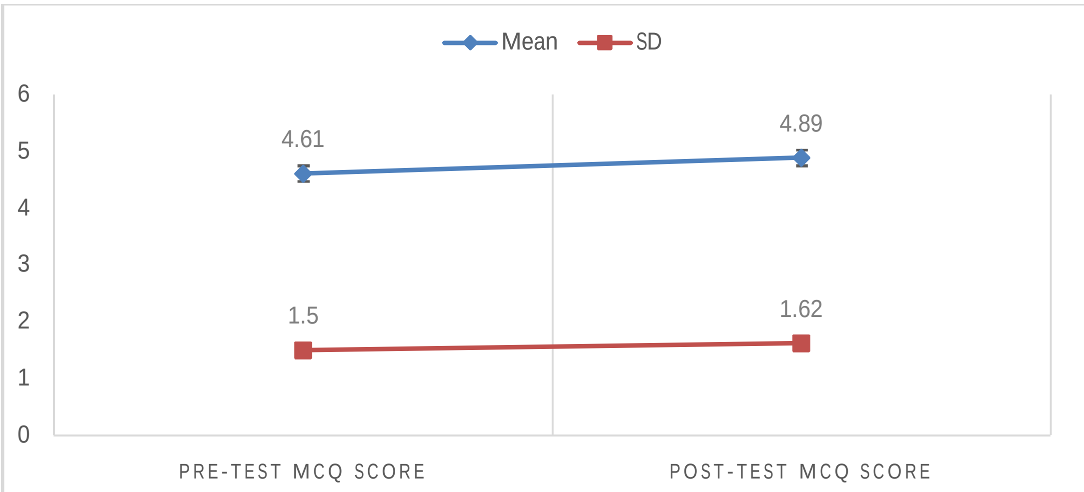

Figure 1: Comparison of Pre-test and Post-test MCQ scores (unpaired t-test).

4. DISCUSSION

HFS-based medical education has been primarily explored in teaching emergency medicine [17, 18]. It has been acknowledged as an essential learning process for technical and non-technical skills [18, 19]. The benefits of SBME has been recognized in enhancing skills but its impact in acquisition of knowledge has not been substantially documented. This may be largely due to the fact that the knowledge outcome was not essentially assessed by a tool with adequate sensitivity and specificity in the earlier studies, perhaps, revealing the mild to moderate effect size of simulation, when compared to alternative learning methods [20, 21]. In our study, we used two different assessment modes: self-reported knowledge scores as perceived by the participants and by the MCQ tests. Self-reported knowledge scores were subjective in nature and taken for four items (see Table 1). These self-reported knowledge assessments were administered to the participants four times ((just before the first HFS session and after each HFS session). MCQ tests were more objective in nature and were taken by the participants just before first HFS session and after the last HFS session. Therefore, we tried to assess the both components of knowledge and observed whether learning has happened or not. There was significant increase in knowledge over time as shown by the self-reported scores (P < .001). Whereas the enhancement of knowledge as determined by the MCQ scores was not statistically significant (P = *.013)*. Several studies have showed that HFS-based teaching technique is either equivalent or superior to traditional teaching methods for the improvement of student's knowledge related to the taught theoretical concepts [6, 7, 22, 23, 24]. Our preliminary study revealed that HFS had significantly enhanced knowledge over time in the management of trauma and surgical emergencies [12]. A study by Ahmad et al (2017) demonstrated that SBME had significantly improved knowledge, skills, and self-confidence of the participants [10]. HPS has significantly enhanced knowledge of students enrolled in adult nursing courses. The results also provide evidence to support the integration of simulation as an effective teaching method that helps to improve student knowledge [25]. Osborne et al (2022) study revealed that HPS-based medical education had significantly enhanced the knowledge of the participants when compared with no intervention or usual teaching [26]. HFS enhanced the knowledge, skills, self-confidence, and satisfaction of the participants in comparison to low fidelity simulation [27, 28]. Our study also revealed that the students participating in HFS sessions showed higher overall post-test scores and enhanced perception of knowledge. By using the five-point ordinal scale, the total score of self-reported knowledge as perceived by the participants had significantly increased over time, $F(2.48, 679.79) = 257.52$, $p < 0.001$. A study by Harris et al (2012) demonstrated a 22% increase in post-test knowledge scores after HFS sessions as perceived by the students [29]. Heitz et al (2009) had evaluated knowledge of the medical students before and immediately after HFS sessions with MCQs. 83% of the participants scored the MCQs correctly after the sessions when compared to 55% before the HFS intervention. The same study using a five-point Likert scale for HFS sessions demonstrated improvement of knowledge in 97% of the participants [30]. A comparative study by Alluri et al (2016) showed significant improvement of post-test scores after the HFS sessions [6]. In our study, the post-test MCQ scores were better but not statistically significant (p value = 0.013). Shultz et al (2016) reported that short-term exposure of medical students to clinical simulation preceding their clerkships can translate into a positive and long-lasting outcome on knowledge, confidence, and skill [31].

There are some studies which showed HFS did not necessarily help in the acquisition of knowledge. HFS-based medical education has proven effective for technical and non-technical skills but its efficacy for acquisition of knowledge is less validated [11]. HFS as a sole learning technique does not increase theoretical knowledge of emergency medicine and, therefore, didactic lectures or pre-reading need to be added to improve theoretical knowledge [32].

SBME has the potential to bridge the gap between theory and practice in acquisition of knowledge and, consequently, expected to be an increasingly recommended educational tool for implementation in the future curriculum.[23,24] Further research is required to understand the benefits of HPS-based medical education that may demonstrate simulation training does actually enhance learners' outcome of knowledge.

Limitations of the study: A potential selection bias could be present during the recruitment as participants with higher academic performances may be more engaged and, therefore, perform better in a supplemental educational activity like HPS training. A part of the study assessments was particularly hard to blind as the evaluation of the learning outcomes was done by comparing the self-reported pre-tests and post-tests scores. It was a single centre study where only final year medical students were included, and as such the findings may not be applicable to other settings.

5. CONCLUSION

Experiential learning is one of the greatest advantages of SBME. This active process helps the learner to construct knowledge by integrating new information and new experience with previous knowledge and understanding. Even though conventional teaching methods may be effective for many students, HFS-based medical education offers an alternative learning tool due to its proactive role in the visual, auditory and kinesthetic senses that ultimately help in the acquisition of knowledge. It may be best recognized as an adjuvant to the undergraduate course curriculum and not a replacement for learning with real patients. Medical undergraduates, by and large, embrace HFS as an efficient learning technique but the positive experience needs to be balanced with the cost-effectiveness, time efficacy, and appropriate assessment outcomes. It cannot fully substitute the need for learning in the clinical environment and, therefore, it is important to consider the logistics and the high cost involved before integrating HFS training with the clinical practice during curriculum development.

CONSENT

All authors declare that 'written informed consent' was taken from all the participants. All information about the participants was kept confidential. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

ETHICAL APPROVAL

Ethical approval was duly obtained from the Ethical Committee / IRB of Manipal University College Malaysia.

REFERENCES

1. Alanazi AA, Nicholson N, Atcherson SR, et al. Use of baby Isao simulator and standardized parents in hearing screening and parent counseling education. Am J Audiol. 2016;25(3):211-23. doi:10.1044/2016_aja-16-0029

2. Jeffries PR, McNelis AM, Wheeler CA. Simulation as a vehicle for enhancing collaborative practice models. Crit Care Nurs Clin North Am. 2008;20(4):471-80. doi:10.1016/j.ccell.2008.08.005

3. Ziv A, Ben-David S, Ziv M. Simulation based medical education: an opportunity to learn from errors. Med Teach. 2005 May;27(3):193-9. doi: 10.1080/01421590500126718

4. Maran NJ, Glavin RJ. Low- to high-fidelity simulation - a continuum of medical education? Med Educ. 2003 Nov;37 Suppl 1:22-8. doi: 10.1046/j.1365-2923.37.s1.9.x

5. Ypinazar VA, Margolis SA. Clinical simulators: applications and implications for rural medical education. Rural Remote Health. 2006 Apr-Jun;6(2):527. Epub 2006 Jun 7

6. Alluri RK, Tsing P, Lee E, Napolitano J. A randomized controlled trial of high-fidelity simulation versus lecture-based education in preclinical medical students. Med Teach. 2016;38(4):404-9. doi: 10.3109/0142159X.2015.1031734. Epub 2015 Apr 21

7. Meyers L, Mahoney B, Schaffernocker T, Way D, Winfield S, Uribe A, Mavarez-Martinez A, Palettas M, Lipps J. The effect of supplemental high fidelity simulation training in medical students. BMC Med Educ. 2020 Nov 10;20(1):421. doi: 10.1186/s12909-020-02322-y

8. Couto TB, Farhat SC, Geis GL, Olsen O, Schvartsman C. High-fidelity simulation versus case-based discussion for teaching medical students in Brazil about pediatric emergencies. Clinics (Sao Paulo). 2015 Jun;70(6):393-9. doi: 10.6061/clinics/2015(06)02. Epub 2015 Jun 1

9. Munshi F, Lababidi H, Alyousef S. Low-versus high-fidelity simulations in teaching and assessing clinical skills. J Taibah Univ Med Sci. 2015;10(1):12–5. https://doi.org/10.1016/j.jtumed.2015.01.008

10. Alanazi AA, Nicholson N, Thomas S. The use of simulation training to Improve knowledge, skills, and confidence among healthcare students: A systematic review. The Internet Journal of Allied Health Sciences and Practice. 2017 Jan 01;15(3), Article 2. doi: 10.46743/1540-580X/2017.1666

11. Cortegiani A, Russotto V, Montalto F, Iozzo P, Palmeri C, Raineri SM, Giarratano A. Effect of high-fidelity simulation on medical students' knowledge about advanced life support: A randomized study. PLoS One. 2015 May 8;10(5):e0125685. doi: 10.1371/journal.pone.0125685

12. Pal B, Kumar MV, Kyaw Soe HH, Pal S. A study on the usefulness of high fidelity patient simulation in undergraduate medical education. The Asia Pacific Scholar. 2018;3(1):42–9

13. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007 May;39(2):175-91. doi: 10.3758/bf03193146

14. ATLS Subcommittee; American College of Surgeons' Committee on Trauma; International ATLS working group. Advanced trauma life support (ATLS®): the ninth edition. J Trauma Acute Care Surg. 2013 May;74(5):1363-6. doi: 10.1097/TA.0b013e31828b82f5

15. Leighton K, Ravert P, Mudra V, Macintosh C. Updating the simulation effectiveness tool: Item modifications and reevaluation of psychometric Properties. Nurs Educ Perspect. 2015 Sep-Oct;36(5):317-23. doi: 10.5480/15-1671

16. Case SM, Swanson DB. Constructing written test questions for the basic and clinical sciences. 3rd ed. Philadelphia: National Board of Medical Examiners; 2001

17. Laschinger S, Medves J, Pulling C, McGraw DR, Waytuck B, Harrison MB, Gambeta K. Effectiveness of simulation on health profession students' knowledge, skills, confidence and satisfaction. Int J Evid Based Healthc. 2008 Sep;6(3):278-302. doi: 10.1111/j.1744-1609.2008.00108.x

18. Rodgers DL, Securro S Jr, Pauley RD. The effect of high-fidelity simulation on educational outcomes in an advanced cardiovascular life support course. Simul Healthc. 2009 Winter;4(4):200-6. doi: 10.1097/SIH.0b013e3181b1b877

19. Aggarwal R, Mytton OT, Derbrew M, Hananel D, Heydenburg M, Issenberg B, MacAulay C, Mancini ME, Morimoto T, Soper N, Ziv A, Reznick R. Training and simulation for patient safety. Qual Saf Health Care. 2010 Aug;19 Suppl 2:i34-43. doi: 10.1136/qshc.2009.038562

20. Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, Erwin PJ, Hamstra SJ. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA. 2011 Sep 7;306(9):978-88. doi: 10.1001/jama.2011.1234

21. Cortegiani A, Russotto V, Naro A, Sanzo G, Grutta G, Raineri SM, Giarratano A. Simulation-based education for cardiopulmonary resuscitation and airway management protocols: a brief report of a systematic review and meta-analysis. Crit Care. 2014;18(Suppl 1):P482. doi: 10.1186/cc13672. Epub 2014 Mar 17

22. Jenkins KD, Stroud JM, Bhandary SP, Lynem L, Choi M, Quick J, Goyal N, Papadimos TJ. High-fidelity anesthesia simulation in medical student education: three fundamental and effective teaching scenarios. Int J Acad Med. 2017;3(1):66-71. doi: 10.4103/IJAM.IJAM_45_17

23. Ka Ling F, Lim Binti Abdullah K, Seng Chiew G, Danaee M, Chan CM. The impact of high fidelity patient simulation on the level of knowledge and critical thinking skills in code Blue Management among undergraduate nursing students in Malaysia. SAGE Open. 2021;11(2):215824402110071. Available at: https://doi.org/10.1177/21582440211007123

24. Alsuwaidi L, Kristensen J, Hk A, Al Heialy S. Use of simulation in teaching haematological aspects to undergraduate medical students improves student's knowledge related to the taught theoretical underpinnings. BMC Med Educ. 2021 May 12;21(1):271. doi: 10.1186/s12909-021-02709-5

25. Jawabreh N, Ayed A, Batran A. Effect of high fidelity simulation on nursing students' knowledge in Palestine. Open Journal of Nursing. 2019;09(04):364–9. doi: 10.4236/ojn.2019.94033

26. Osborne C, Brown C, Mostafa A. Effectiveness of high- and low-fidelity simulation-based medical education in teaching cardiac auscultation: a systematic review and meta-analysis. International Journal of Healthcare Simulation [Internet]. 2022 Jul 29 [cited 2023 Jan 8]. Available from: https://doi.org/10.54531/nzws5167

27. Nimbalkar A, Patel D, Kungwani A, Phatak A, Vasa R, Nimbalkar S. Randomized control trial of high fidelity vs low fidelity simulation for training undergraduate students in neonatal resuscitation. BMC Res Notes. 2015 Nov 3;8:636. doi: 10.1186/s13104-015-1623-9

28. Basak T, Unver V, Moss J, Watts P, Gaioso V. Beginning and advanced students' perceptions of the use of low- and high-fidelity mannequins in nursing simulation. Nurse Educ Today. 2016 Jan;36:37-43. doi: 10.1016/j.nedt.2015.07.020. Epub 2015 Jul 29

29. Harris DM, Ryan K, Rabuck C. Using a high-fidelity patient simulator with first-year medical students to facilitate learning of cardiovascular function curves. Adv Physiol Educ. 2012 Sep;36(3):213-9. doi: 10.1152/advan.00058.2012

30. Heitz C, Brown A, Johnson JE, Fitch MT. Large group high-fidelity simulation enhances medical student learning. Med Teach. 2009 May;31(5):e206-10. doi: 10.1080/01421590802637990

31. Shultz CG, Cooke JM, Denay KL, Llanes M, Zazove P, Kelley SA. The effect of simulation based training on medical students' perceptions, knowledge, and skill at baseline and 6 month follow up. Int J Innov Educ Res [Internet]. 2016 May 1 [cited 2023 Jan. 7];4(5):151-65. Available from: https://scholarsjournal.net/index.php/ijier/article/view/547

32. Cowling L, Swartzberg K, Groenewald A. Knowledge retention and usefulness of simulation exercises for disaster medicine - what do specialty trainees know and think? Afr J Emerg Med. 2021 Sep;11(3):356-360. doi: 10.1016/j.afjem.2021.05.001. Epub 2021 Jul 22