



The Efficacy of High-fidelity Simulation-based Education in Enhancing Knowledge among Undergraduate Medical Students

Bikramjit Pal ^{a*}, M. V. Kumar ^b, Htoo Htoo Kyaw Soe ^c
and Sudipta Pal ^c

^a Department of Surgery, RCSI & UCD Malaysia Campus (RUMC), Penang, Malaysia.

^b Department of Surgery, Manipal University College Malaysia, Melaka, Malaysia.

^c Department of Community Medicine, Manipal University College Malaysia, Melaka, Malaysia.

Authors' contributions

This work was carried out in collaboration among all authors. Author BP designed the study, wrote the protocol, conducting the study and wrote the first draft of the manuscript. Author MVK wrote the protocol, conducting the study and wrote the first draft of the manuscript. Author HHKS designed the study, performed the statistical analysis and managed the analyses of the study. Author SP wrote the protocol, managed the literature searches and the analysis of the study. All authors read and approved the final manuscript.

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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

*Corresponding author: E-mail: bikramjit.pal@rcsiucd.edu.my, drbikramjitpal@gmail.com;

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: In the unpaired t-test, Post-test MCQ scores were higher than Pre-test scores but not statistically significant ($P = .013$). A one-way repeated measured ANOVA with Bonferroni post hoc analysis demonstrated that 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 immensely in this context [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 objective of this 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 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.

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 $< .001$ 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 1).

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 (Table 2).

Table 1. 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%

Table 2. 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

Table 3. Comparison of Pre-test and Post-test MCQ scores (unpaired t-test)

Unpaired t-test			P value
Variable	MCQ scores Mean (SD)	Mean difference (95% confidence interval)	
Pre-test	4.61 (1.50)	0.28 (0.06, 0.50)	.013
Post-test	4.89 (1.62)		

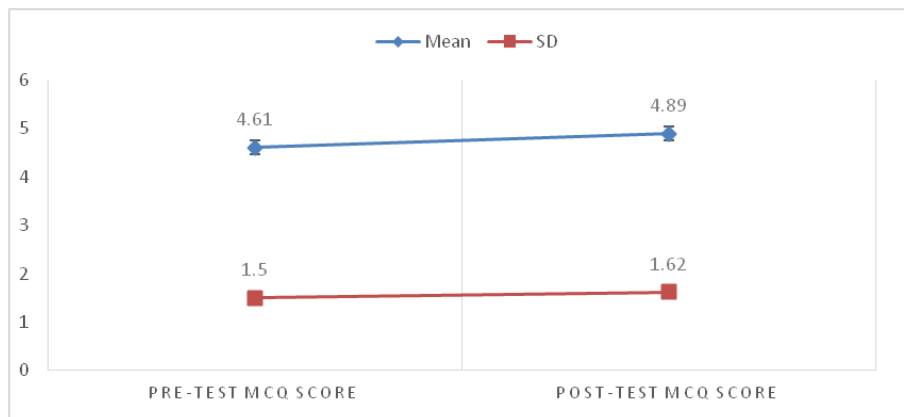


Fig. 1. Comparison of Pre-test and Post-test MCQ scores (unpaired t-test)

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 (Table 3) and represented in Fig. 1.

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 this study, the researchers used two different assessment modes: self-reported knowledge scores as perceived by the participants and also by the MCQ tests. Self-reported knowledge scores were

subjective in nature. 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, the researchers 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 [6,7,22-24]. 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]. This 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 this 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 [24,25]. 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.

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.

6. 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.

CONSENT

All authors declare that 'written informed consent' was taken from all the participants. All information about the participants was kept confidential.

ETHICAL APPROVAL

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

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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