Original Article

Effect of using appendectomy surgical simulation software on academic achievement: Game-based learning during the COVID-19 pandemic

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Abstract

Background & Objective: Regarding the urgent needs of students for an efficient teaching methodology, it is necessary to use self-directed and self-centered teaching methods that encourage the power of reasoning and judgment. This study aimed to investigate the effect of using the game-based Appendectomy Surgical Simulation software on the academic achievement of undergraduate operating room students in Khomein, Iran.

Materials & Methods: This quasi-experimental study was conducted during the COVID-19 pandemic. Forty undergraduate operating room students who were in the second semester of the first year of the operating room undergraduate program participated in this quasi-experimental single-blind study. The participants were assigned randomly to the control and intervention groups after their consent was obtained. Following the use of the game-based Appendectomy Surgical Simulation software for the intervention group and lecture-based classes on a specific academic learning software for the control group, the data were collected using a researcher-made questionnaire concerning academic achievement, whose validity and reliability were approved. The data were then analyzed using descriptive and analytical tests in IBM SPSS (version 22) at a significance level of $P<0.05$.

Results: The average score of academic achievement was significantly higher in the intervention group (58.35±2.38) than in the control group (35.65±4.14) ($P<0.05$).

Conclusion: Using the game-based Appendectomy Surgical Simulation software has been effective in improving the academic achievement of students during the COVID-19 pandemic and afterward. Therefore, it can be used in academic and educational programs.

Keywords: academic achievement, COVID-19, gamification, medical education, operating room, simulation

Introduction

The operating room field is one of the disciplines that relies largely on an individual's practical and clinical skills. The first mistake in surgery can be the last one and cause an irreparable accident for the patient (1). At the end of the last century, multiple reports from the World Health Organization, the Organization for Economic Cooperation and Development, and the Commonwealth Fund emphasized persistent gaps in healthcare quality and safety across the world (2). The Institute of Medicine documented high rates of preventable medical errors and demanded a fundamental change in the healthcare delivery system. One of the 13 recommendations in their report was the need to restructure medical education to be consistent with the principles of the 21st century health system. The traditional approach to medical education is to continually reduce healthcare tasks to simpler or smaller components, such as facts or simple skills, for the purpose of teaching (3).

Lecture-based classes are one of the traditional and widely accepted teaching methods that are cost-effective and transfer knowledge to a large number of students at a specific time. However, studies have shown that about 80% of the training provided by this method is forgotten within eight weeks (4). Therefore, due to the limitations of lecture-based classes and considering the urgent need of students for an efficient and learner-centered

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educational method, it is necessary to use a method that leads to the continuity of learning, results in satisfaction, and strengthens critical thinking skills (5). Electronic learning (E-learning), as a kind of self-centered learning, is one of the phenomena of the modern world that has emerged in the information age in knowledge-based societies. The main feature of E-learning is its communicative and interactive characteristics (6). Simulation is a kind of E-learning method designed to generate experience without passing through the actual event, providing an opportunity to learn courses such as internships that are not easily accessible in a safe environment (3). Simulation can provide a safe environment to reflect and learn from mistakes without any threats to professional identity (7). While educational simulation will never replace practical education, it can provide an inexpensive and effective environment for practicing the required skills (8). In addition, the active participation of students in a simulation environment plays a significant role in gaining knowledge (9). In the meantime, the COVID-19 pandemic changed vocational education. Most universities have decided to discard the classroom training method and rely on virtual or distance education (10). During this pandemic, surgical education was highly affected since the students were not able to physically attend clinical centers, and the number of surgeries declined. Therefore, virtual methods and surgical simulation software played an important role in education during the COVID-19 pandemic (11).

One of the indicators for evaluating the quality of students' education is their academic achievement (12). Achievement means success in a job or duty, and academic achievement is the result of education, which shows how far the student, teacher, or institution has achieved their educational goals (13). The low academic achievement of learners always indicates the inefficiency of teaching methods selected by teachers (14). The effect of simulation education as a learner-centered educational method on students' academic achievement is controversial, and there is a research gap in the literature on the effect of these educational methods on students' academic achievement and performance, especially in medical studies (15). Despite the fact that operating room students are constantly forced to perform different, sophisticated, and aggressive procedures in the operating room and always experience great stress during their internships due to the nature of the disciplines in which they are studying, there is no simulated surgery software to improve their performance. Accordingly, we decided to design one for operating room students (as scrub nurses) in surgeries. Therefore, this study aimed to investigate the effect of using the game-based Appendectomy Simulation software on the academic achievement of undergraduate operating room students in Khomein, Iran.

Materials & Methods

Design and setting(s)

This was a quasi-experimental, single-blind study. There were two main variables in this study: a) the students' score of assessment in an educational content exam, and b) the score of academic achievement in a self-administered questionnaire. This study was conducted in the 2020-2021 academic year during the COVID-19 pandemic in the School of Nursing, Khomein University of Medical Sciences, Khomein, Iran.

Participants and sampling

The study population consisted of undergraduate operating room students. The sample size was calculated using G*power 3.1.9.4 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany; (http://www.gpower.hhu.de/) as 18 cases. Totally, 40 students were included in this study. To ensure equal group sizes, a randomization procedure was implemented. Following the selection of a total of 40 students for the study, they were assigned randomly to either the intervention or the control group. An automated computer-generated random number sequencer was used to carry out this randomization process. Consequently, 20 students were allocated to the intervention group, and an additional 20 students were assigned to the control group. This random assignment technique was employed to mitigate potential biases and guarantee an equal number of participants in each group. The inclusion criteria were as follows: 1) students who passed the theoretical and practical part of the Information Technology course and accessed the virtual education system of the university (the Adobe Connect platform and the Navid system (special software for university learning in Iran), which is an Iranian platform) and possessed a computer equipped with a webcam, and 2) students who were in their first year of bachelor's study (2nd semester) and willing to participate in the current study. Students holding a certificate in "educational software", working in surgical centers, or being reluctant were not included in the study. None of

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those invited declined to take part or met the exclusion criteria. The flow diagram is presented in Figure 1.

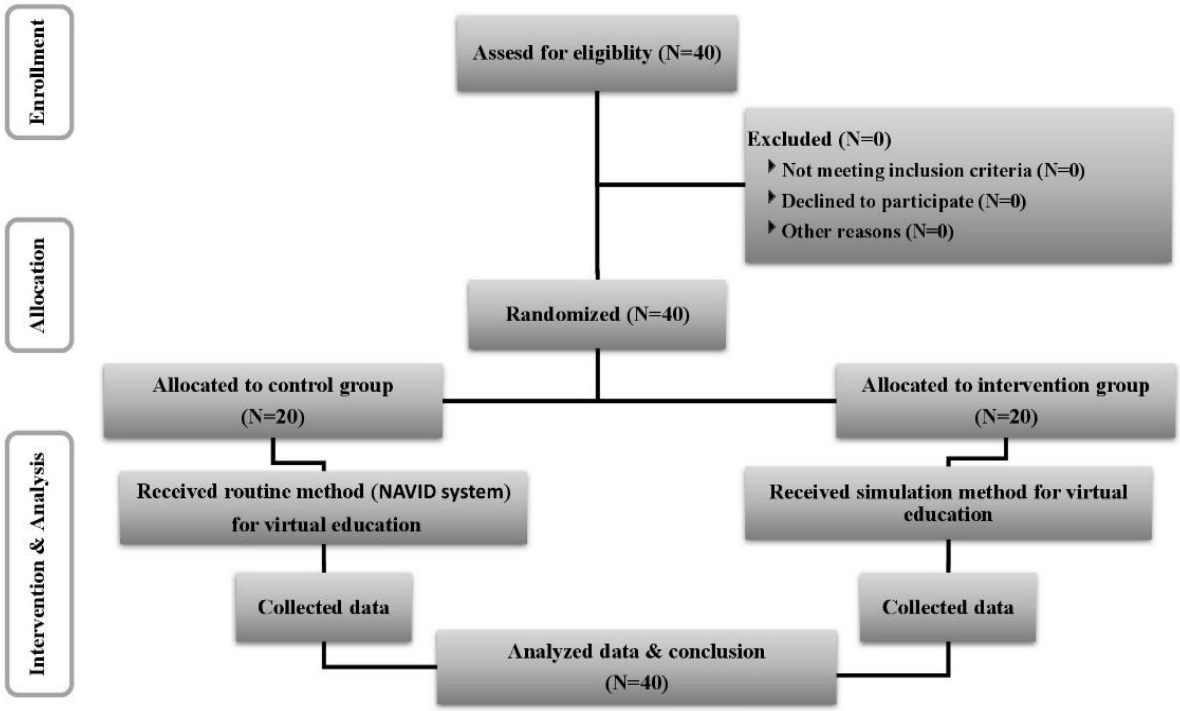

Figure 1. The flow diagram of the study

Tools/Instruments

The data collection tools were a multiple-choice exam that tested the educational content (about appendectomy surgical instruments and how they are used during the procedure) and a self-administered questionnaire concerning academic achievement. The questionnaire on academic achievement was designed based on the questionnaire of "comparing academic achievement in virtual education with traditional education" (16). The academic achievement questionnaire was virtually completed by the students in both groups in one session after the completion of the study. This questionnaire consisted of 15 questions, and each question was designed based on a five-point Likert scale, including strongly agree (5), agree (4), neither agree nor disagree (3), disagree (2), and strongly disagree (1). The minimum and maximum scores were 15 and 75, respectively, with a high score indicating higher academic achievement. The pilot study was performed using an academic achievement questionnaire whose reliability was approved through Cronbach's alpha, which was calculated at 0.84. To conduct this pilot study, 16 undergraduate operating room students were selected and randomly divided into two groups of eight, and after the educational intervention, they completed the questionnaire. Ten experts, who were the faculty members of clinical affairs from the universities of medical sciences of Isfahan, Khomein, and Shiraz, approved the validity of the academic achievement questionnaire and the educational content exam through online Delphi and face-to-face techniques. The Delphi method resulted in an excellent degree of agreement among the 10 experts. Our research and communication with the panel were sent via email and categorized as 'e-Delphi' under the Delphi subcategory. As a guideline for implementing the e-Delphi method, the first step in addressing a problem or question is to identify it. Once the problem or question has been identified, a panel of experts who have knowledge and experience relevant to the problem or question should be selected. The panel is then administered a series of questionnaires or rounds using electronic communication. The responses are analyzed qualitatively or quantitatively to identify areas of agreement and disagreement among the experts. The results are provided to the panel in subsequent rounds, with the goal of achieving a convergence of opinions.

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The results can then be used to generate answers to questions, facilitate the prioritization of responses, and target solutions to problems (17). The educational content exam consisted of 20 multiple-choice questions designed by the researcher and held simultaneously for both the control and intervention groups in the virtual exam system of the university.

Data collection methods

Due to the COVID-19 pandemic and since the in-person university classes were closed, the students in the intervention group attended a virtual class for two hours on Adobe Connect to get acquainted with the instruments of appendectomy surgery and how these instruments are used during this procedure. Moreover, the students in the intervention group got acquainted with how to work with the game-based appendectomy surgical simulation software during this virtual session. They completed the software steps under the supervision of the researcher (using a webcam). This software was designed in 2019 as a master's thesis for the operating room discipline at Isfahan University of Medical Sciences and was approved with an approval ID of 396875 (18). The content of the software included information about surgical instruments, learning how to prepare the surgical table, and using the instruments during the appendectomy surgery. The scenario of appendectomy surgery can be found in the help section of the software before initiating the steps. In the first step of this software, the pictures of the appendectomy surgical instruments are displayed, and the user has to find and choose the name of the instrument among the four available options. In the second step, the user has to place the surgical instruments on the surgical table based on their order of use during the surgical procedure. In the third stage, the user has to choose the instrument required for each stage of the surgery from the table and hand it over to the surgeon. In each stage, the user receives feedback from the software. In the control group, students became familiar with appendectomy surgical instruments and how they are used during this procedure with the help of the Navid system, which is used for holding academic courses virtually. Using this system, the appendectomy surgical instruments and how they are used during this procedure were described with the help of PowerPoint and lectures during online sessions. In order to minimize selection and measurement biases, the study was conducted on the relevant population, and the validity and reliability of the tools were approved.

Data analysis

Data were analyzed by IBM $SPSS_{v22}$ (international business machines corporation statistical product and service solutions version 22) using descriptive statistics (frequency and relative frequency for qualitative variables and mean and standard deviation for quantitative variables) and inferential statistics (chi-squared test for comparing nominal qualitative variables, t-test for comparing parametric variables, Mann-Whitney U test for comparing non-parametric variables, and Kolmogorov-Smirnov tests at $P<0.05$ level of significance for normality of the distribution), as shown in Figure 1.

Results

A total of 40 students participated in this study, with 20 in the control group and 20 in the intervention group. There were 25 (62.5%) females and 15 (37.5%) males. Characteristics (age and GPA(grade point average)) were similar between groups (Table 1). Based on Table 1, the independent sample t-test results did not show a significant difference in age and GPA between the intervention and control groups ($P>0.05$).

Table 1. Determining and comparing the frequency distribution of age in two groups under study (n=40 in both groups)

Variable	Group	Average	Standard Deviation	P-value
Age	Control	19.80	1.15	0.527
	Intervention	19.55	1.32	
GPA	Control	16.66	1.39	0.642
	Intervention	16.49	0.98	

Abbreviations**:** GPA, grade point average; P, probability

Students in the intervention group scored significantly higher on exams measuring educational content and academic achievement than the control group, as shown in Table 2. The average academic achievement score of the intervention group (58.35±2.38) was significantly higher than that of the control group (35.65±4.14) ($P<0.05$) on a scale of 15-75.

Based on the Pearson correlation coefficient, the results (Table 3) indicated no significant relationship between age, GPA, and educational content exam scores of

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students in the control and intervention groups and their academic achievement (P>0.05).

Table 2. Determining and comparing the operating room students' academic achievement scores and educational content exam scores in two control and intervention groups

Variable	Group	Number	Average	Standard Deviation of Average	P-value
Academic Achievement Score	Control	20	35.65	4.14	0.001
	Intervention	20	58.35	2.38	
Educational Content Exam Score	Control	20	14.25	1.71	0.001
	Intervention	20	18.40	1.16	

Note: *The significance level is less than 0.05
Abbreviations: P, probability,

Table 3. Relationship between variables in two groups based on Pearson correlation coefficient test

Group	Relationship of variables	Correlation Coefficient	P-value
Control	Age with Academic Achievement Score	-0.103	0.666
	GPA with Academic Achievement Score	-0.008	0.973
	Educational Content Exam Score with Academic Achievement Score	0.323	0.165
Intervention	Age with Academic Achievement Score	-0.027	0.912
	GPA with Academic Achievement Score	-0.196	0.407
	Educational Content Exam Score with Academic Achievement Score	-0.198	0.402

Note:The significance level is less than 0.05
Abbreviations:P, probability

Discussion

The results of this study showed that using simulation software increased students' academic achievement and the average score of academic achievement of the students in the intervention group was higher than that of the control group. Moreover, the results of this study showed that there was no significant relationship between the demographic characteristics of students, including their age, gender, GPA, and academic achievement. Research has shown that the systematic integration and use of technology, especially audiovisuals such as simulation models, may help to arouse students' interest and enhance their academic achievement (19). Our results were consistent with previous studies that showed simulation education improves students' academic achievement. Ibezim and Asogwa examined the effect of computer simulation models on students' academic achievement in computer logic. This quasi-experimental study was performed on intervention and control groups. The intervention group was trained using a computer simulation model, and the control group was trained through conventional teaching approaches. The results of this study showed that the academic achievement score of the students who were trained using the simulation model was significantly higher than that of the group trained through conventional teaching approaches (13). Safdari et al. showed that if educational simulation software is used along with traditional methods, the students will gain better knowledge, and a lot of the shortcomings of lecture-based classes and clinical presence will be removed (20). Nehring et al. also noted that using Peer Wise (a web-based game-developing tool) improved the performance of students and found it valuable for their learning (21). Sedigh et al. investigated the effect of using the game-based Appendectomy Surgical Simulation software on the self-efficacy of undergraduate operating room students. They reported that the average score of self-efficacy in the intervention group was higher than that of the control group, and the difference was statistically significant (8). There is still considerable uncertainty regarding the implementation of simulation education. Contrary to the findings of the present study, Koyunlu et al. examined the effect of combining analogy-based simulation and laboratory activities on Turkish elementary school students' understanding of simple electric circuits. The results of the electricity performance test (EPT) indicated that the combination of analogy-based simulation and laboratory activities caused statistically greater learning acquisition than the analogy-based simulation and laboratory activities alone (22). In Bai et al.'s study, despite the buzz around gamification as an exciting new method to engage students, evidence of its ability to enhance learning was mixed since gamification does not bring additional utility and can also cause anxiety or jealousy (23). The difference between the results of the two mentioned studies and those of this study may be due to the difference in the research environment, the sample size, and the type of study. Leif Rune Hedman and Li Felländer-Tsai concluded that, when used appropriately, simulation training can be a highly effective additional training tool in the development and maintenance of technical skills. This is also effective for temporarily

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non-performing orthopedic surgeons during a crisis such as the COVID-19 pandemic (11). Guillermo et al. performed a study entitled "the role of virtual reality simulation in surgical training in the light of COVID-19 pandemic". They found that all trainees improved their surgical skills during the structured VR (virtual reality) simulator training (24). According to the results of this study, it can be concluded that using the game-based Appendectomy Surgical Simulation software during the COVID-19 pandemic and afterward is effective in improving students' academic achievement and can be included in the students' curriculum. One of the limitations of this study was the small sample size and the lack of control over individual characteristics affecting academic achievement. Therefore, it is suggested that this study be conducted on a larger statistical population to investigate the individual characteristics affecting students' academic achievement.

Conclusion

Along with the development of technology and science and the current pandemic situation, moving from traditional teaching methods to online methods can create opportunities for educational improvement (25). A practical learning system that cannot be done directly at the hospital location or a face-to-face learning system in a situation such as the COVID-19 pandemic cannot be done. Therefore, using the simulation, operating room students can still experience practice in a digital atmosphere. The simulation software tested in this study went well, and the positive effects of this method on the educational achievement of students were confirmed.

Ethical considerations

This study was approved by the Ethics Committee of Khomein University of Medical Sciences, Khomein, Iran (IR.KHOMEIN.REC. 1399.010). Written consent was obtained from all participants. In addition, at the end of the study, the software was provided to students in the control group who were willing.

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Disclosure

None.

Author contributions

Conceptualization: SB
Data curation: MG
Methodology/formal analysis/validation: SB, SJ
Project administration: SB, AS
Funding acquisition: none
Writing – original draft: SB, AS
Writing – review & editing: SB, AS, MG, SJ.

Data availability statement

The data that support the findings of this study are available from the corresponding author.

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