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Impact of Simulation-based Education on Learning Outcome and Technology Acceptance in Postgraduate Anatomy Students

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Background: Simulation-based education is an effective method for developing students practical skills. Considering the importance of the anatomy course and the growing need for modern teaching approaches, the aim of the present study was to investigate the effect of simulation-based education on learning outcomes and technology acceptance of Master of Science students in the field of anatomy.
Method: This study was based on an interventional design. Twenty Master of Science students in the field of anatomy were divided into two groups: a control group (taught with traditional lectures) and an experimental group (taught with fixed cadaver simulator software). Learning was assessed based on students' academic scores and technology acceptance was assessed using Chen's Technology Acceptance Questionnaire. Data were analyzed using SPSS 26, software employing the independent t-test and Pearson's correlation coefficient.
Results: There were significant differences between the experimental and the control groups in learning outcomes ($p = 0.01$) and technology acceptance ($p = 0.01$). Analysis of statistics revealed significant differences in the subscales of perceived ease of use ($p = 0.03$) and perceived insecurity ($p = 0.02$) between the two groups. Additionally, there was a significant correlation between learning score and age ($p = 0.003$) as well as gender ($p = 0.001$).
Conclusion: Compared to traditional lecture-based method, simulation-based education significantly enhanced learning and increased technology acceptance among Master of Science students in anatomical sciences. Furthermore, individual factors such as age and gender were associated with learning performance. These findings suggest that simulation-based methods can serve as effective tools in teaching practical and complex subjects such as anatomy.

Keywords: Students, Simulation training, Anatomy, Learning, Education

تأثير التعليم القائم على المحاكاة على نتائج التعلم وقبول التكنولوجيا لدى طلاب الدراسات العليا في علم التشريح

الخلفية: يُعدّ التعليم القائم على المحاكاة أسلوبًا فعّالًا لتطوير المهارات العملية للطلاب. ونظرًا لأهمية مقرر علم التشريح والحاجة المتزايدة إلى مناهج تدريس حديثة، فقد هدفت هذه الدراسة إلى دراسة تأثير التعليم القائم على المحاكاة على نتائج التعلم وتقبل التكنولوجيا لدى طلاب ماجستير العلوم في مجال علم التشريح.
الطريقة: اعتمدت هذه الدراسة على تصميم تدخلي. قُسّم عشرون طالبًا من طلاب ماجستير العلوم في مجال علم التشريح إلى مجموعتين: مجموعة ضابطة (دُرّست باستخدام المحاضرات التقليدية) ومجموعة تجريبية (دُرّست باستخدام برنامج محاكاة الجثث الثابتة). قُيّم التعلم بناءً على الدرجات الأكاديمية للطلاب، وقُيّم تقبلهم للتكنولوجيا باستخدام استبيان تشن لقبول التكنولوجيا. حُللت البيانات باستخدام برنامج SPSS 26، وهو برنامج يستخدم اختبار t المستقل ومعامل ارتباط بيرسون.
النتائج: وُجدت فروق ذات دلالة إحصائية بين المجموعتين التجريبية والضابطة في نتائج التعلم ($p = 0.01$) وتقبل التكنولوجيا ($p = 0.01$). كشف تحليل الإحصاءات عن فروق جوهرية في المقاييس الفرعية لسهولة الاستخدام المُدركة ($p = 0.03$) وانعدام الأمن المُدرك ($p = 0.02$) بين المجموعتين. بالإضافة إلى ذلك، كان هناك ارتباط جوهري بين درجة التعلم والعمر ($p = 0.003$) والجنس ($p = 0.001$).
الخلاصة: بالمقارنة مع الطريقة التقليدية القائمة على المحاضرات، عزز التعليم القائم على المحاكاة التعلم بشكل ملحوظ وزاد من قبول التكنولوجيا بين طلاب ماجستير العلوم في العلوم التشريحية. علاوة على ذلك، ارتبطت عوامل فردية مثل العمر والجنس بأداء التعلم. تشير هذه النتائج إلى أن الأساليب القائمة على المحاكاة يمكن أن تكون أدوات فعالة في تدريس المواد العملية والمعقدة مثل علم التشريح.

الكلمات المفتاحية: الطلاب، التدريب على المحاكاة، علم التشريح، التعلم، التعليم

تأثیر آموزش مبتنی بر سیمولاتور بر پیامد یادگیری و پذیرش فناوری در دانشجویان تحصیلات تکمیلی آناتومی

زمینه و هدف: آموزش مبتنی بر شبیه‌سازی روش آموزشی مؤثر برای توسعه مهارت‌های عملی دانشجویان است. با توجه به اهمیت درس آناتومی و نیاز به کارگیری روش‌های نوین تدریس، هدف از تحقیق حاضر، بررسی تاثیر آموزش مبتنی بر شبیه‌سازی بر یادگیری و پذیرش فناوری دانشجویان کارشناسی ارشد رشته علوم تشریح بود.
روش: این پژوهش از نوع مداخله ای بود. ۲۰ نفر از دانشجویان کارشناسی ارشد رشته علوم تشریح به دو گروه کنترل (آموزش دیده با سخنرانی) و گروه تجربی (آموزش دیده با نرم افزار شبیه سازفیکس جسد) تقسیم شدند. یادگیری براسلس نمره دانشجو و پذیرش فناوری براسلس نمره پرسشنامه پذیرش تکنولوژی چن سنجیده شد. داده ها با نرم افزار SPSS و آزمون تی مستقل و ضریب همبستگی پیرسون تجزیه و تحلیل گردید.
یافته‌ها: اختلاف معناداری میان دو گروه کنترل و تجربی از نظر یادگیری ($p = 0.01$) و پذیرش تکنولوژی ($p = 0.01$) وجود داشت. آنالیز آماری تفاوت معنی داری در حیطه عدم سهولت ($p = 0.03$) و عدم امنیت ($p = 0.02$) بین دو گروه کنترل و تجربی نشان داد. همبستگی معنی داری بین نمره یادگیری با سن ($p = 0.003$) و جنسیت دانشجویان ($p = 0.001$) وجود داشت.
نتیجه گیری: آموزش مبتنی بر شبیه‌سازی در مقایسه با روش سنتی سخنرانی موجب بهبود یادگیری و افزایش پذیرش فناوری در دانشجویان کارشناسی ارشد علوم تشریح شد. همچنین، عوامل فردی مانند سن و جنسیت با میزان یادگیری مرتبط بودند. این نتایج نشان می‌دهد شبیه‌سازی می‌تواند روش مؤثری در آموزش دروس عملی مانند آناتومی باشد.

واژه های کلیدی: دانشجویان، آموزش شبیه سازی، آناتومی، یادگیری، آموزش

پوسٹ گریجویٹ اناٹومی طلباء میں سیکھنے کے نتائج اور ٹیکنالوجی کی قبولیت پر نقلی بنیاد پر تعلیم کا اثر

پس منظر: تخروپن پر مبنی تعلیم طلباء کی عملی صلاحیتوں کو فروغ دینے کا ایک مؤثر طریقہ ہے۔ اناٹومی کورس کی اہمیت اور جدید تدریسی طریقوں کی بڑھتی ہوئی ضرورت کو مدنظر رکھتے ہوئے، موجودہ مطالعے کا مقصد اناٹومی کے شعبے میں ماسٹر آف سائنس کے طلباء کے سیکھنے کے نتائج اور ٹیکنالوجی کی قبولیت پر تخروپن پر مبنی تعلیم کے اثرات کی چھان بین کرنا تھا۔
طریقہ: یہ مطالعہ ایک مداخلتی ڈیزائن پر مبنی تھا۔ اناٹومی کے شعبے میں سائنس کے بیس ماسٹر طلباء کو دو گروپوں میں تقسیم کیا گیا تھا: ایک کنٹرول گروپ (روایتی لیکچرز کے ساتھ پڑھایا جاتا ہے) اور ایک تجرباتی گروپ (جسے فکسڈ کیڈیور سمیلیٹر سافٹ ویئر کے ساتھ پڑھایا جاتا ہے)۔ سیکھنے کا اندازہ طلباء کے تعلیمی اسکور کی بنیاد پر کیا گیا اور چن کے ٹیکنالوجی قبولیت کے سوالنامے کا استعمال کرتے ہوئے ٹیکنالوجی کی قبولیت کا اندازہ لگایا گیا۔ ڈیٹا کا تجزیہ SPSS 26 کا استعمال کرتے ہوئے کیا گیا، سافٹ ویئر جو آزاد ٹی-ٹیسٹ اور پیئرسن کے ارتباطی گنانک کو استعمال کرتا ہے۔
نتائج: تجرباتی اور کنٹرول گروپس کے درمیان سیکھنے کے نتائج ($p = 0.01$) اور ٹیکنالوجی کی قبولیت ($p = 0.01$) میں نمایاں فرق تھے۔ اعداد و شمار کے تجزیے سے دونوں گروپوں کے درمیان سمجھی جانے والی آسانی ($p = 0.03$) اور سمجھی جانے والی عدم تحفظ ($p = 0.02$) کے ذیلی پیمانے میں نمایاں فرق سامنے آیا۔ مزید برآں، سیکھنے کے اسکور اور عمر ($p = 0.003$) کے ساتھ ساتھ جنس ($p = 0.001$) کے درمیان ایک اہم تعلق تھا۔
نتیجہ: روایتی لیکچر پر مبنی طریقہ کے مقابلے میں، تخروپن پر مبنی تعلیم نے سیکھنے کو نمایاں طور پر بڑھایا اور جسمانی علوم میں ماسٹر آف سائنس کے طلباء میں ٹیکنالوجی کی قبولیت میں اضافہ کیا۔ مزید برآں، انفرادی عوامل جیسے عمر اور جنس سیکھنے کی کارکردگی سے وابستہ تھے۔ یہ نتائج بتاتے ہیں کہ تخروپن پر مبنی طریقے اناٹومی جیسے عملی اور پیچیدہ مضامین کی تعلیم میں موثر ٹولز کے طور پر کام کر سکتے ہیں۔

کلیدی الفاظ: طلباء، نقلی تربیت، اناٹومی، سیکھنا، تعلیم

INTRODUCTION

With the increasing advancement of technology, electronic educational environments have gained a special status. Simulator educational software is one of the achievements introduced with the aim of improving the quality of education. In the field of medical science, virtual reality and simulation are widely used in surgery and anatomy (1-3). Simulation is a representation of some real devices or work situations and aims to display some behavioral aspects of one system through the behavior of another system. Simulation-based education, as an effective educational method, increases the development of practical skills and critical thinking by integrating the knowledge and skills of learners (1-3). Simulation in a fictitious situation can recreate the real effects of some possible conditions and provide the learner with an environment that is as close as possible to the real environment, while being less costly and risky than facing the real environment. This can be used effectively in education (4-7). By simulating the real environment, interactive learning is facilitated for students at a low cost and leads to behavior modification by engaging them with the learning environment. One of the simulation methods is virtual simulation, in which real people use simulated equipment in a simulated environment (4-7). Studies show that simulators increase student learning and performance, especially in medical and related fields. Simulation provides the opportunity to master skills that can be acquired through continuous practice and repetition with a simulator (4-7).

Some studies have suggested that students' clinical vision improves after training with a simulator (8-11). For example, a 2019 study involving 292 undergraduate students used virtual dissection to teach the anatomy of the thorax, abdomen, pelvis, and spinal cord. The results of this study showed that 78.7% of students stated that digital dissection improved students' understanding of the material of participants. They also stated that digital dissection enhanced their understanding of the material and clinical vision (8). Swain et al., conducted a study titled "The Role of Simulator Software in Microcontrol Education" which showed that this software had a significant positive impact on student learning (9). Wolffe et al., used a simulation tool in their study. In this study architecture students were divided into two groups: control and intervention. The results indicated that this tool had a favorable effect on students' learning (10).Another study also reported a significant improvement in learning outcome following the use of a combination of virtual dissection and traditional cadaver dissection (11). As antomy is a basic and challenging discipline, there is a continued need to employ innovative and engaging educational methods to ensure high-quality education. The present study was, therefore, conducted with the objective of checking for the effectiveness of simulation-based education on Master of Science (MSc) students' learning and acceptance of technology within the field of anatomy.

METHODS

This was an interventional study that was approved by the Ethics Committee of Mashhad University of Medical Sciences (Ethics code: IR.MUMS.REC.1400.260). The statistical populationwas 20 MSc students in the field of anatomy at Mashhad University of Medical Sciences who were included in the study using a convenience sampling method. The inclusion criterion was willingness to participate in the study and the exclusion criterion included students who had chosen this course for the second time. The students were divided into two control and experimental groups. The control group consisted of 11 people who were not trained with the fixed cadaver simulator software and only the lecture method was used for them. The experimental group consisted of 9 people who were trained using the fixed cadaver simulator software. The same professor taught both groups.

Designing the Body Fix Simulator Software

In the first step, educational objectives were defined according to the course title. In the second step, educational content and software scenario were developed. The third step involved designing the software using the C# programming language and Unity 3D simulation software (version 2019), which is one of the most powerful game development and design platforms across various systems. In the fourth step, debugging and testing were conducted to ensure the software was fully functional and practical before deployment. During the fifth step, the simulator was introduced to the students, familiarizing them with the environment and simulation tools. An explanation of the scenarios and instructions on how to operate different parts of the software were provided, alongside a short introductory video. In the sixth step, students in the experimental group worked individually with the software (figure 1). Finally, learning outcomes were measured based on students' scores, and technology acceptance was evaluated using the standard Technology Acceptance Questionnaire developed by Chen et al. (13).

Study tool

The standard 18-item Technology Acceptance Questionnaire developed by Chen (2014) was used. This questionnaire comprises four domains: optimism (5 items), creativity (5 items), difficulty (4 items), and insecurity (4 items). Responses were scored on a Likert scale ranging from 1 (very low)

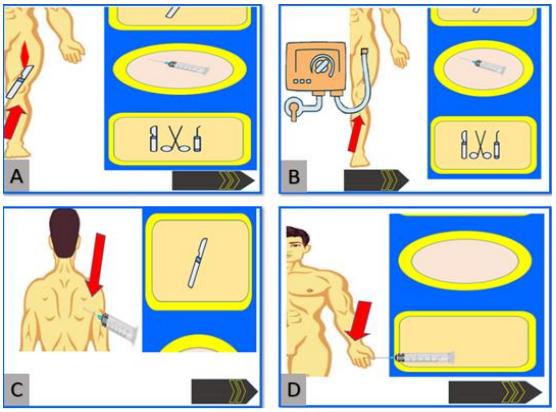

Figure 1. View of the cadaver fixation simulator software
(A) Femoral artery section.
(B) Insertion of the pump tube for fixative solution injection.
(C) Injection of fixative solution into the back region for supplementary fixation.
(D) Injection of fixative solution into the palm for additional fixation

to 5 (very high). Face and content validity were confirmed based on the opinions of the supervisor as well as those of several professors, specialists, and experts. The reliability of this questionnaire has also been supported by the research conducted by Noori et al., and Chen et al., (12, 13). Cronbach's alpha coefficients were 0.85 for optimism, 0.78 for creativity, 0.91 for difficulty, and 0.71 for insecurity. The score interpretation of the questionnaire is as follows: Scores between 18 and 36 were considered to indicate a low level of variability within the population, scores between 36 and 72 represented a moderate level of variability, and scores above 72 were classified as indicating a very good level of variability.

Analysis Method

After data collection, the data were entered into SPSS version 26 and summarized using descriptive statistics, including frequency, mean, and standard deviation. Inferential analyses were performed using the independent t-test and Pearson correlation coefficient.

RESULTS

Table 1 shows the participants' demographic data in the study. Of the 20 students, 12 (60%) were females and 8 (40%) were males. Of these, 5 males (45.5%) were in the control group, and 3 (33.3%) were in the experimental group. The frequency distribution of the gender, place of residence, and marital status of the students are shown in Table 1. There was no significant difference between the control and experimental groups with respect to gender (p = 0.21), place of residence (p = 0.50), and marital status (p = 0.83) (all p > 0.05).

Table 2 shows the mean scores of students' learning and technology acceptance. Statistically, it was discovered that there exists a significant difference between the experimental and control group in learning (p = 0.01) and technology acceptance (p = 0.01). There was no significant difference between groups in optimism (p = 0.81) and creativity (p = 0.45) areas, whereas differences existed in the absence of ease (p = 0.03) and insecurity (p = 0.02) areas.

There was a strong relationship between learning scores, age (p = 0.003), and gender (p = 0.001). There were no strong relationships for learning scores and marital status (p = 0.36) or place of residence (p = 0.38). Furthermore, there were no significant correlations between technology acceptance scores, age (p = 0.07), gender (p = 0.13), marital status (p = 0.33), or place of residence (p = 0.52).

Table 1. Demographic characteristics of participants in the two study groups

Characteristics		Control group	Experimental group
Age Mean (SD)		30.18 (1.99)	30.62 (2.50)
Gender N (%)	Female	6 (54.5%)	6 (66.6%)
	Male	5 (45.5%)	3 (33.3%)
Place of residence (percentage)	Dormitory	9 (81.8%)	3 (33.3%)
	No-dormitory	2 (18.2%)	6 (66.6%)
Marital status (percentage)	Single	8 (72.7%)	3 (33.3%)
	Married	3 (27.3%)	6 (66.6%)

Table 2. Comparison of learning levels and technology acceptance in the two study groups

Characteristics		Control group	Experimental group
Learning Mean (SD)		7.54 (0.56)	9.12 (0.35)*
Technology acceptance Mean (SD)	Optimism	17.72 (2.61)	22.5 (2.67)
	Creativity	16.81 (2.52)	22.5 (2.67)
	Inconvenience	13.18 (2.52)	8.75 (4.43)#
	Insecurity	9.54 (5.22)	9.37 (4.17)**
	Total domains	57.27 (2.61)	63.12 (7.03)*

The average learning score increased significantly compared to the control group (* p = 0. 01).
The average technology acceptance score increased significantly compared to the control group (* p = 0. 01).
The average difficulty score decreased significantly compared to the control group (** p = 0. 03).
The average insecurity score decreased significantly compared to the control group (# p = 0. 02).

DISCUSSION

There were significant differences between the experimental and the control groups in learning outcomes and technology acceptance. Analysis of statistics revealed significant differences in the subscales of perceived ease of use and perceived insecurity between the two groups. There was a significant correlation between learning score and age, as well asgender. The results of this study demonstrated a significant difference between the mean learning and technology acceptance scores of students in the control and experimental groups. Similarly, Yakura et al. (2022) investigated the effect of simulation-based education on the initial training of medical students. Their findings indicated a significant increase in students' self-efficacy scores and written test results, while satisfaction levels remained relatively unchanged. Additionally, the implementation of simulator-based education was associated with a reduction in injury incidence. Therefore, simulator-based education can effectively enhance anatomical skills and knowledge in dissection courses (14). Patterson et al. (2010) also reported improvements in both students' satisfaction and learning outcomes following the design and implementation of a multimedia laboratory simulator for chemistry education (15).

Many medical education programs still rely heavily on traditional methods of teaching anatomy, such as using cadavers and textbooks. However, new technologies such as simulators can significantly enhance the learning process. Although some studies have investigated the effects of using simulators in anatomy education, there is still insufficient data to comprehensively evaluate and compare learning outcomes with traditional methods. In addition, there is still a lack of understanding of the benefits of using simulators in anatomy education. This gap could lead to the lack of adoption of these technologies in educational programs. There is a need to investigate the impact of simulator training on the clinical abilities of medical students, especially in the field of diagnosing and treating diseases. Incorporating simulators in anatomy education can lead to improved quality of evidence-based teaching and learning. This, in turn, could have a positive impact on students' clinical performance (16-18).

In 2019, Darras et al., conducted an integration of dissection into medical anatomy courses. The aim of the study was to investigate the feasibility of integrating virtual dissection into a cadaver-based medical anatomy course and to assess students' overall attitudes towards it. Two hundred and ninety-two first-year medical students were enrolled in the study. The virtual dissection lab was integrated into a cadaver-based anatomy course. After the course, students completed a short survey that was developed using a theoretical framework for evaluating the curriculum. The results showed that 78.7% of students believed that the virtual dissection lab increased their understanding of cadaver anatomy and its clinical applications. 73.8% of students believed that the virtual dissection lab was an effective use of laboratory time. 61.5% considered it a strength of the curriculum. The researchers concluded that blended learning enhanced learning (19). In the present study, training with simulator software also improved understanding of the anatomy course.

Bush et al. (2023) integrated the use of a virtual dissection laboratory in an undergraduate speech and hearing anatomy and physiology course. Nine students, divided into two focus groups, were invited to share their experiences and thoughts regarding the pedagogical methods and practical exercises within the dissection laboratory. The results showed that this method led to a better understanding of the course material compared to traditional methods. Further, this method of education, particularly in speech and language, enabled learning through the use of models and cadavers (20). Further, in the present study, simulator training was accepted by the students and resulted in high satisfaction.

Funjan et al. (2023) conducted a study involving 99 medical students to compare the perceptions of high- and low-performing students regarding the effectiveness of virtual dissection, interaction, accessibility, technical usability, and learning. The study used a validated questionnaire consisting of 20 closed and 15 open-ended questions, administered via Google Forms. Responses were measured on a five-point Likert scale. The results showed that 73.03% of students agreed that virtual dissection is an effective tool for understanding the lectures better. Additionally, 75.28% stated that virtual dissection should serve only as a complement to cadaver dissection in learning anatomy. Moreover, 61.79% believed that virtual dissection motivates study. 70.78% of participants believed that it led to better academic performance. In addition, 64.04% considered it to promote continuous learning, and 78.65% felt that it facilitated deep learning. Furthermore, 47.19% believed it helped reduce anxiety in learning anatomy (21).

According to constructivist theory, the use of simulators and active learning tools enables students to use their experiences to construct concepts. Moreover, simulators help reduce cognitive load and manage learning effectively. Based on our search, very few studies have been conducted on this topic, which is one of the strengths of this research. However, including a pre-test would have improved the study (22-23). Similarly, feedback was provided to learners after the tasks to enhance their future performance, and a

reflective facilitation was conducted, which is recommended for future researchers to consider. One of the limitations of this study was its single-center nature and small sample size.

CONCLUSION

The findings of this study demonstrate that simulation-based education significantly enhances learning outcomes and increases technology acceptance among students of anatomical sciences. The notable difference between the group trained using simulation software and the group taught through traditional lectures highlights the effectiveness of modern teaching methods in improving practical understanding of anatomical concepts. Furthermore, the results suggest that factors such as ease of use and perceived security when interacting with technology influence its acceptance. Furthermore, the significant relationship between learning outcomes and variables such as age and gender indicates that individual student characteristics may impact the effectiveness of educational approaches. Therefore, the use of simulation as an effective instructional tool—particularly in hands-on courses like anatomy—is strongly recommended.

Ethical Considerations:

Ethical issues including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc. have been completely observed by the authors. This study was approved by the Ethics Committee of Mashhad University of Medical Sciences (Ethics Code: IR.MUMS.REC.1400.260).

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