BMC Nursing

RESEARCH

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Nursing student's perceptions, satisfaction, and knowledge toward utilizing immersive virtual reality application in human anatomy course: quasi-experimental

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Abstract

Background A paradigm shift in nursing education is required to prepare Z generation of nursing students through integrated innovative technologies as teaching strategies such as immersive virtual reality in several bioscience and main courses to facilitate and enhance learning process.

Aim/objective Examine the effect of utilizing an immersive virtual reality application on students' perceptions, knowledge, and satisfaction in an anatomy course.

Methods A quasi-experimental (pre-post test, one group) design was conducted among 1st year nursing students ($N=138$) enrolled in an anatomy course in the spring semester of 2023–2024 in the nursing program in the health professions faculty at Al-Quds University. The technology acceptance model (TAM) was used for data collection.

Results The results showed that 96% of participants were satisfied with using the VR application, and it retains their knowledge in the human anatomy course. 92% of the total, were under the age of twenty, and 84% were females. 80.1% (2.99 ± 0.58) of those students had more positive perspectives of VR applications in the nursing courses. Additionally, there were significant differences in students' satisfaction and knowledge toward using VR applications after the anatomy lecture ($p=0.029$, $p=0.05$, respectively).

Conclusion Virtual reality is a supplemental innovative tool for promoting learning. Nursing students perceive immersive virtual reality technologies positively and prefer using three-dimensional images in their anatomy courses, which helps them recall their knowledge, understand concepts of educational content, identify learning objectives, and improve learning outcomes. This study found that virtual reality can improve nursing students' understanding, satisfaction, and knowledge of anatomy.

Keywords Virtual reality, Immersive virtual reality, Nursing education, Anatomy education

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Introduction

Nowadays, healthcare environments are complex and constantly developing, caused by the rapid evolution of information technology [1, 2]. Consequently, nursing educators seek to transform nursing education through the integration of theoretical knowledge into innovative teaching strategies among digital-age students called the Z-generation [3, 4]. Generation Z students are digital natives who want visually enhanced teaching methods and technology-enhanced learning opportunities and appreciate the practical application of knowledge [5, 6]. Therefore, an effective way to engage these students is to present innovative teaching strategies to make a difference in their education process [5].

VR technology is one of the most interesting computer-based technology developments of the present time, it is a method of creating an environment simulation and enabling user interaction [7], through immersing individuals in a cooperative three-dimensional (3D) world, which includes a head-mounted device that uses motor, auditory, and visual inputs to combine full-body movement with an environment that mimics reality in all respects—that is called immersive virtual reality [8, 9].

Immersive VR allows students to live an active experience through virtual scenarios provided in a simulated environment that fosters active participation, immersion, multisensory stimulation, and improved learning outcomes without distractions through mutual collaboration among context, behavior, and personal characteristics [10–12]. Also, this form of virtual reality is an effective technique in nursing education that is used alongside traditional approaches [13], through the application of a variety of software to help nurse students acquire skills, such as airway management, phlebotomy training, intravenous catheter insertion, and teaching chemotherapy administration, etc. [11, 14, 15].

In nursing education, students have prior educational experience through the lecture model in several nursing courses; however, immersive virtual reality is not typically used in the general education setting. So, nurse educators seek to support student learning in virtual classroom settings by applying Kolb's experiential learning theory, which emphasizes the value of reflecting on, understanding, engaging, and applying to virtual environments [16, 17], through inserting immersive virtual reality as teaching strategies that help students progress educational journey, provide safe nursing instruction, develop science self-efficacy, promote higher study skills, encourage independent study, incorporate active learning, and provide activities that fit various methods of learning [18–20].

One of these basic courses that is addressed in this study is bioscience subjects like anatomy and physiology, which are often taught in the first year of nursing programs by sitting in a classroom and listening to a teacher read a PowerPoint, which leads sometimes to limited understanding and a lack of ability to gain knowledge and maintain it [21, 22]. Therefore, nurse educators apply immersive VR technologies in anatomy education as teaching tools, allowing students to visualize and imagine anatomical models and structures in 3D [23] and interact with real imagery for a dynamic without being limited by ethical considerations, a lack of donations, or the need to visit an anatomy lab [11, 24–26].

So, the importance of this study is to integrate immersive virtual reality technique as a teaching strategy in several courses and procedures in nursing education by encouraging nursing students known as the Z generation to use advances in technology to achieve their educational purposes through game-based learning based on immersive virtual reality applications, to improve and maintain their knowledge alongside traditional lecture models, increase their satisfaction and self-efficacy, and enhance their motivation and engagement in their educational process. Thus, this study aims to examine the effect of utilizing an immersive virtual reality strategy on students' perceptions, knowledge, and satisfaction in an anatomy course based on using a VR human anatomy application (musculoskeletal system).

Research questions

- What are nursing students' perceptions toward utilizing immersive VR applications before and after attending an anatomy course (theory)?
- Is there a significant difference between students' satisfaction and knowledge with VR utilized applications before and after taking an anatomy course?
- Is there a significant differences between the socio-demographics of students and their total perceptions toward utilizing immersive VR applications?

Methodology

Study design

Quasi experimental (pre-post test; one group) design was utilized, some virtual reality-based learning studies used this type of design, usually involving an initial observation of the phenomenon of interest performed in a virtual simulated environment, then introducing an intervention (training, new equipment, new procedures, etc.), and it was adopted to demonstrate causality between the intervention and its outcome [27]. In this study, human anatomy VR application was used, before and after taking Musculoskeletal system chapter in anatomy course.

Setting

The study was conducted in the Al-Quds business center for innovation, technology, and entrepreneurship (BCITE) of the health professions faculty at Al-Quds university, Palestine.

Participants

In the spring semester of the 2023–2024 academic year, 205 first-year nursing program students enrolled in a three-hour-per-week anatomy course. G*power 3.1 was used to determine the purposive sample size for students who completed the anatomy course's musculoskeletal system chapter. The calculation took into account alpha = 0.05, a medium effect size, a 5% margin of error, and the inclusion of the entire 205 population with a 95 confidence interval (CI) [28]. 134 undergraduate nursing students were included in the sample size as a result. Our purposeful sample, $N = 138$, was larger than the necessary sample size. The same participants used immersive VR human anatomy applications before and after taking musculoskeletal theory lectures.

Inclusion criteria

All of the freshman year nursing students (1st year) registered in Anatomy course, which is a specialization requirement course in the nursing curriculum at Al-Quds university, in the spring semester 2023–2024 academic year, who attended musculoskeletal system chapter in this course (theory). Also, who applied the virtual reality application (Human Anatomy VR for Institutions) through using Meta Quest 2 (Immersive All-In-One VR Headset).

Data collection instruments

Part 1 Socio-demographic information

Based on previous research [29, 30], the researcher created a questionnaire that asked participants about their gender, age, grade average, place of residence, information technology proficiency, most digital tools they used for educational purposes, and whether or not they had access to the internet at the residence. Moreover, there were questions regarding their previous experience of virtual reality, frequency of playing video games, and suffering from motion sickness during VR experience, as well as students' satisfaction toward VR-based learning and whether they think VR applications help to gain knowledge in their courses. The questionnaire had a 0.896 reliability rating.

Part 2 Technology Acceptance Model (TAM)(student perception survey)

Davis' Theory of Reasoned Action served as the foundation for the creation of the Technology Acceptance Model (TAM) [31, 32]. It offers a theoretical relationship between users' perceptions, attitudes, intentions, and acceptance or rejection of the use of technology and is used to evaluate the behaviors related to the use of technology in the workplace and/or in educational settings [32, 33]. The TAM is a useful instrument for evaluating students' responses to new technology to enhance teaching and learning methods [33, 34], which is widely utilized in the healthcare environment and health information technology [35]. In addition, TAM includes eight factors rated on a 7-point Likert scale from "strongly agree" to "strongly disagree," namely, perceived usefulness (PEU) (4 items), perceived enjoyment (PE) (3 items), intention to use (EUS) (3 items), subjective norms (SN) (2 items), use of sustainability (4 items), social networking (NE) (3 items), student learning achievements (SSA) (5 items), and engagement (6 items) (Cronbach's $\alpha = 0.89–0.97$) [32].

In line with the study's aim of examining the effect of using immersive virtual reality applications in anatomy courses on students' perceptions, satisfaction, and knowledge, the researchers evaluated the instrument's content and face validity [36]. Researchers conducted an extensive literature search to confirm the validity of the content, synthesis, and consolidation [37]. They adopted the TAM instrument, which was developed by Huang & Liaw (2018), Shin (2017), and Sprenger & Schwaninger (2021). was based on the acceptance of virtual reality as new technology; it includes six factors and 24 questions, which were designated to rate students' views on the ease of use (6 questions), interaction (3 questions), imagination (3 questions), immersion (3 questions), motivation (4 questions), and intention to use (5 questions), and used a 5-point Likert scale ranging from 1 (strongly disagree) through 5 (strongly agree), with 5 being the highest score and 1 being the lowest score [38–40]. Then, they confirmed the format of the questions without changing their meaning to ensure the meaning equivalency (Polit & Beck, 2017), with the addition of open-ended question that explain the perceptions and attitudes of students toward utilizing immersive virtual reality in nursing education. The reliability of the questionnaire was analyzed using the Statistical Packages for the Social Sciences (SPSS) to obtain Cronbach's alpha value, which was (0.958) This indicated that the questionnaire was highly reliable [41](see Table 1).

Procedures

Alquds University's Chief of the Al-Quds Business Center for Innovation, Technology, and Entrepreneurship (BCITE) and the Scientific and Ethics Research Committees gave their approval for the researchers to conduct this study in the center, which has all the necessary immersive virtual reality tools (3D Meta-Quest 2, head-mounts, trackings, show screens, etc.). In each

Table 1 Reliability of Technology Acceptance Model scale (TAM)

Item	Cronbach's Alpha	No of items
Ease of use	0.831	6
Interaction	0.891	3
Imagination	0.837	3
Immersion	0.872	3
Motivation	0.900	4
Intention to use	0.904	5
Total	0.958	24

VR Meta-Quest 2 ($n=5$), the researcher confirmed that the Human Anatomy VR application from the Meta Store (https://www.meta.com/experiences/human-anatomy-vr-for-institutions/3662196457238336/) had been installed.

Students were then instructed to attend a 15–20 min researcher-led lecture that went over the objectives of the study, VR resources, and trial runs. Students were also allowed to share any issues they may have had about the experience and ask questions. 138 participants were split into ten groups, with ten to fifteen students in each group.

Before the anatomy lecture (theory; musculoskeletal chapter), VR application (human anatomy; musculoskeletal system) was performed for the first time; each group selected a day that fit into their schedule and did not conflict with any other classes. The researcher and facilitators (7 students in the fourth year) helped the participants use and wear the VR tools. In addition, all of the participants in the experiment were put in a WhatsApp group, and they were given a link to a Google Form to complete the questionnaire, including in the first section, informed consent after learning the purpose of the study. In the second section, demographic information (age, gender, grade average, etc.). And, in the last section, they were required to complete a TAM scale to examine their perceptions toward utilizing the immersive VR (Human Anatomy VR) application for the first time. This duration was 2 weeks.

After the anatomy lecture (theory; musculoskeletal chapter), VR application (human anatomy) was performed for the second time after 2 weeks for the same students; each group decided on a day that fit their schedule and did not conflict with any other classes. The same process was conducted, and they were given a link to a Google Form to complete the TAM scale to examine their perceptions toward utilizing the immersive VR (human anatomy VR) application after taking their anatomy lecture. Data collection from participants at the date of the anatomy course, from March 10 to April 26, 2024 was performed (see Fig. 1).

Fig. 1 Nursing students through utilizing VR application (Human anatomy)

Ethical considerations

Before data collection, approval from the Scientific and Ethics Research Committees of Al-Quds University was obtained (RESC/2024-22). Students were informed about the purpose of the study, and that participation in the study was voluntary; they had the right to accept or refuse to participate. Confidentiality was ensured during the study. Data were coded with numbers for identification – names were not used. No one other than the researcher had access to the codes. In addition, participants were informed filling out a questionnaire via online Google-form will be considered informed consent, and they have the option to withdraw their consent.

Data analysis

All statistical procedures were analyzed using SPSS, version 27 [42]. The assumptions for each test were checked before conducting the test. Descriptive statistics were conducted to calculate the means, standard deviation (SD), and frequencies of the study variables. Furthermore, independent samples t-tests were conducted to compare students' perception and satisfaction toward utilized VR applications before and after lecture in anatomy course, while a one-way analysis of variance (ANOVA) was used to test mean differences for variables with 2 or more categories.

Results

Students' sociodemographic characteristics

Regarding the findings of student demographics associated with utilizing immersive VR technology in anatomy courses, this study showed that 127 participants, or 92% of first-year nursing students, were under the age of twenty, which confirms that our study addresses the Z generation who are adapted to use new technology. 84% were females, 64% of total had a GPA of 80–89% and lived in the city, thus 84.5% of them use the internet nearly half day, 57% of total participants had basic technological skills, and used mobile phones and laptops as primary digital tools during their course (39%, 34%, respectively). Although 74% of them use virtual reality technology from once to a lot of time. 34% and 33% of them never and/or once a day play a video game, respectively, which confirmed using technology for educational purposes. Regarding motion sickness as VR symptoms, 40.5% of them reported not experiencing these symptoms. Thus, 96% of them indicated their satisfaction with utilizing VR-based learning, and 83.3% said it is a useful tool for gaining knowledge in nursing courses. (see Table 2)

Students perceptions toward utilized VR application before and after human anatomy lectures

The results of the study showed that nursing students perceived positive about taking human anatomy courses utilizing virtual reality (VR). After attending lectures, 80.1% (2.99±0.58) of those students had more positive perspectives of VR applications. Even though students' perceptions of the VR application's ease of use are the lowest before and after the lecture (68.1%, 70.5%; 2.73±0.69, 2.80±0.61; respectively), there is a higher intention to use, motivation, and immersion toward it after the lecture (3.14±0.70, 3.11±0.65, 3.00±0.70; respectively) with a percentage (85.9, 85, 82; respectively). (see Table 3)

Students perceptions based on socio-demographic factors

Although most of the participants of this study were female (84%), there is no significant statistical difference between nursing students' perceptions toward the utilized immersive VR application in human anatomy lectures and gender ($p>0.05$). Also, there were positive and significant differences between nursing students' perception toward the utilized immersive VR application in human anatomy lectures and age after taking the lecture ($p=0.002$) and grade point average (GPA) before taking the lecture ($p=0.004$). In addition, there were significant differences in utilized VR application (before and after the lecture) with experienced students with video games ($p=0.001$, $p=0.015$; respectively), and there were significant differences in students' satisfaction and knowledge toward using VR application after the lecture ($p=0.029$, $p=0.05$, respectively). (see Table 4)

Discussion

As a result of the study's students' perceptions toward utilizing immersive VR applications in anatomy courses, there was no significant difference among genders, despite the majority of participants being female ($p>0.05$). This aligns with the findings of a previous study by [43], which suggested that females may be more inclined to utilize technology in educational settings due to expectations or perceived social norms that emphasize digital competency in a traditionally male-dominated field. This is in line with the results of another previous study by [44], in which females frequently demonstrate greater capacities of communication, cooperation, and flexibility in learning contexts mediated by technology; these are essential competencies for making successful use of new technologies in educational settings. These results point to a complicated interaction between gender dynamics in education and the nursing profession, suggesting that there may be differences in how male and female students perceive and react to the learning environment, especially when it comes to perspectives and satisfaction with new technologies.

In addition, the findings of this study showed there was a significant difference between nursing students' perceptions toward utilizing immersive VR applications and

Table 2 Students demographics data ($n=138$)

Variable	Value	F	%
Gender	Male	22	16%
	Female	116	84%
Age	≥ 20	127	92%
	20–24	11	8%
GPA	90–100%	35	25%
	80–89%	88	64%
	70–79%	15	11%
Residency	City	89	64.5%
	Village	39	28.5%
	Camp	10	7%
Information technology skill level at enrollment	None	3	2%
	Limited	44	32%
	Basic	79	57%
	Advanced	12	9%
Which digital tool used during course work?	labtop	47	34%
	Mobile phone	54	39%
	Tablet	27	20%
	None	10	7%
How often do you play video games?	Never	47	34%
	Once a day	46	33%
	Several times a day	33	24%
	Don't know about video games	12	9%
How many hours per day, on average, do you use the internet?	Less than 6 h	60	43.5%
	7–12 h/day	57	41%
	13–18 h/day	13	9.5%
	More than 19 h/day	8	6%
How much experience do you have with VR?	None	36	26%
	Used once	48	35%
	Used several times	44	32%
	Used a lot	10	7%
Do you suffer from motion sickness?	Never	56	40.5%
	Rarely	31	22.5%
	Sometimes	43	31%
	Frequently	8	6%
Are you satisfied with your VR based learning experience?	Yes	132	96%
	No	6	4%
Do you think you gain knowledge in nursing courses when using virtual reality applications?	Yes	115	83.3%
	No	23	16.67%

Table 3 Students' perception toward utilized VR application before and after human anatomy lecture

Domain	[B] VR* (M ± SD)	[A] VR* (M ± SD)	Before (%)	After (%)
Ease of use	2.73 ± 0.69	2.80 ± 0.61	68.1%	70.5%
Interaction	2.88 ± 0.75	2.99 ± 0.75	77.9%	79.3%
Imagination	2.93 ± 0.71	2.95 ± 0.73	76.1%	78.1%
Immersion	2.96 ± 0.62	3.00 ± 0.70	78.8%	82%
Motivation	2.98 ± 0.68	3.11 ± 0.65	79%	85%
Intention to use	2.95 ± 0.73	3.14 ± 0.70	79%	85.9%
Total	2.89 ± 0.60	2.99 ± 0.58	76.5%	80.1%

*[B] VR = Before anatomy lecture * [A] VR = After anatomy lecture

the age characteristic after taking the lecture on anatomy ($p<0.01$), which indicated they integrated their theory knowledge with basic technological knowledge; this is reasonable considering their generational development since they usually associate game-based learning with Generation Z [3, 45]. Also, they exploit the accessibility of the internet and use digital tools like smartphones and laptops for academic purposes, whenever and wherever they are, according to a similar study by [46].

Regarding previous studies, there are some factors, like the kind of virtual environment and transition from a pleasant to a scary environment, causing users to experience motion sickness, a well-known side effect that prevents the VR community from fully utilizing this

Table 4 Students perceptions toward using VR application and their demographic characteristics

		[B] VR*		[A] VR*	
Variable	**Value**	**M ± SD**	***P*-Value**	**M ± SD**	***P*-Value**
Gender	Male	2.89 ± 0.51	0.316	2.69 ± 0.58	0.668
	Female	2.78 ± 0.63		2.73 ± 0.71	
Age	Less than 20 years old	2.79 ± 0.62	0.934	2.69 ± 0.70	**0.002**
	20–24 years old	2.86 ± 0.51		3.15 ± 0.39	
GPA	90–100%	3.10 ± 0.50	**0.004**	2.75 ± 0.74	0.085
	80–89%	3.03 ± 0.57		2.90 ± 0.54	
	70–79%	2.99 ± 0.58		3.16 ± 0.57	
How often do you play video games?	Never	3.03 ± 0.47	**0.001**	2.98 ± 0.59	**0.015**
	Once a day	3.15 ± 0.44		2.84 ± 0.60	
	Several times a day	2.94 ± 0.60		3.01 ± 0.51	
	Don't know about video games	2.34 ± 0.91		2.41 ± 0.72	
	Sometimes	2.89 ± 0.68		2.98 ± 0.68	
	Frequently	2.92 ± 0.67		2.71 ± 0.68	
Are you satisfied with your VR based learning experience?	Yes	3.01 ± 0.57	0.279	2.87 ± 0.61	**0.029**
	No	2.59 ± 0.54		3.25 ± 0.24	
Do you think you gain knowledge in nursing courses when using virtual reality applications?	Yes	2.90 ± 0.59	0.129	2.90 ± 0.58	**0.05**
	No	2.75 ± 0.81		2.83 ± 0.71	

*[B] VR = Before anatomy lecture * [A] VR = After anatomy lecture

immersive technology [47–49]. So, in this study, the researchers examined whether students suffered from motion sickness while utilizing immersive VR in human anatomy applications; there indicated no significant difference between their perceptions toward using VR technology and their feeling of motion sickness ($p > 0.05$), and 40.5% of them did not get motion sickness, which indicates the immersive VR application that designs for educational purposes is less likely to cause this effect against extreme VR gaming—which involves "shooting," "falling," and "squirrel jumping" [50–52], which should be taken into consideration in the current techniques of VR design. On the other hand, related to academic performance through determining the grade point average (GPA) of the previous semester (s). This study's results showed there was a significant difference between students' perceptions toward utilizing immersive VR application in a human anatomy course and their GPA before taking their lecture ($p < 0.01$); the majority of them's average was 80–89% (very good), which indicated students seek to develop their understanding of the learning goals and improve their academic performance through developing their skills and knowledge by engaging in innovative teaching activities like immersive VR applications to maintain their cognitive and psychomotor skills [49, 53].

Furthermore, through the broad market availability of affordable software and hardware tools for VR environments, a merge of game-based techniques such as video games and VR environments may boost learning and training methods. As a result, students may actively participate in such learning environments, enabling the development of exploration-based learning models at any time and anywhere [54]. Thus, the researchers in this study examined whether students play video games frequently, which showed there were significant differences between students' perceptions toward using immersive VR applications and the frequency of playing video games ($p < 0.05$), which indicated the digital generation's competence with technology, and immersive VR applications are one of the beneficial games that enhance learning and training [54]. Video games can also be powerful learning tools that students find highly engaging and enhance learning skills in a self-directed learning environment [55–57].

Students perceptions toward utilized VR application before and after human anatomy lectures

The findings of this study showed that there were significant differences in students' satisfaction with using VR applications after the lecture ($p < 0.05$). Satisfaction is a feeling of acceptance, which originates from the outcome of an event and the individual's prior expectations of themselves [58]. Nurse student satisfaction is associated with greater engagement and motivation in the teaching and learning process, as motivated students learn more and better, focus on patient-centered care, and demonstrate effective teamwork in healthcare settings ([59, 60].

In this study, nursing students showed a high level of motivation (3.11 ± 0.65) toward using VR after the lecture. Because students appeared ready for innovative technologies like VR, they showed motivation, self-control, and a willingness to learn, which is linked to

the immersive and unique nature of VR that promotes experiential learning by doing, which agrees with studies [61–63]. Additionally, this study showed a higher level of student immersion, imagination, and interaction toward using VR after taking course than before, in which human anatomical VR application flexibility and design, including lighting, audio, special effects, and animation, are features allowing students to place themselves within the game and engage freely in a realistic and standardized way and engage with the virtual cadaver (by e.g., standing inside a system or structure), which is consistent with studies of [64–67] found the use of VR features motivates students, promotes self-monitoring, and increases their satisfaction.

In this study, nursing students showed an intention to use VR applications in human anatomy courses to find information that has a learning effect to enhance their perceived value because they believe that these tools offer major benefits compared with traditional learning, perceived enjoyment, and satisfaction, which students' intentions to use considered a significant factor in determining an individual's motivation to routinely use technology or endorse it to others [32]. Thus, students will develop positive attitudes toward its adoption in their learning [46, 68–70]. Furthermore, students' technological learning motivation is reflected in their mastery and familiarity with technical skills, thus significantly influencing their intention to use VR applications [71]. Despite the ease of use domain being the lowest perception among students in this study, it was higher after taking lectures than before. This can be explained by the students' initial interest in and curiosity about virtual reality (VR) applications, as well as their later realization of unrealistic expectations and anxiety with the technology limitations of the VR, as well as primary communication barriers like shyness, fear, and language [72, 73].

This study also showed that there were significant differences between students' perceptions toward utilizing immersive VR human anatomy applications and the gain of knowledge after attending a lecture on human anatomy ($p=0.05$) because immersive VR applications let students visualize and spatially interact with anatomical structures in a unique 3D context. Consequently, it promoted their understanding of spatial relationships of one anatomical structure to another, which can be very challenging in the theory lecture. In addition, immersive VR applications demonstrated that visualization was an effective way to explore anatomy-specific concepts that led to improved learning outcomes. These findings agreed with the studies of [66, 74–77] indicated immersive VR in the anatomy course increases the level of students' confidence in their knowledge and development of their communication skills; it has the potential to bridge the knowledge gap between theory and practice, particularly in the areas of learning improvement, use of encouragement, and fostering an appreciation for the use of 3D pictures in anatomy teaching [24, 78]. It also enables students to acquire the necessary skills and information in a safe environment [29, 79].In addition, regarding maintaining knowledge, students are used to learning objectives based on cognitive and memorizing, which requires them to recognize, anticipate, or analyze theories and concepts. Thus, the variability of VR design in nursing education improved teaching and achieving learning goals [75, 80].

To explore students' perspectives, the researchers queried them about their experiences with the immersive VR application in human anatomy courses. 89 (64.5%) of students were responded. The quotes represent students who had very positive VR experiences.

Students' responses highlighted the benefits of VR:

"I found that using the VR program helped me understand the musculoskeletal lesson the best..." (Student A).

This aligns with other students' views on VR's ability to enhance spatial understanding:

"For example, you can walk inside the vertebral column and see exactly where the bone markers are..." (Student B).

VR interaction was also a key theme:

"I enjoyed it because it allowed me to accomplish matters and interact with it that I couldn't do with traditional lectures..." (Student C).

While not all students may have had uniformly positive experiences, several reported better exam performance:

"I was pleased with my exam performance when I recognized the questions that related to the musculoskeletal lecture. Immediately, I recalled and imagined all of the bones and muscles. I think VR technology is a beneficial tool to maintain and retain our knowledge after a period. I suggest integrating this technology in human anatomy courses and other courses in nursing curricula." (Student D).

These findings echo previous studies examining the relationship between immersive VR application usage and students' comprehension and perceptions of anatomical spatial relationships and reflect a self-perceived gain of knowledge, which may correlate to an enhanced understanding of human anatomy [11, 66, 78, 81, 82].

Limitation of study

The limitations of this study are that the findings may be limited to specific geographic regions and educational settings; it was conducted in one course and for one level of students. Future research should replicate this study with randomly selected, larger sample sizes from different regions and several medical fields to minimize the limitations of this study. Also, other limitations represent technical issues that faculties and universities can address by sharing other multidisciplinary technological fields. It would also be beneficial to include teachers to address any possible differences between groups, which would require interpretation from a different point of view. Moreover, the survey instrument should be enhanced by researchers to assess students' actual application of VR technology, even after its validity and reliability have been tested. Consequently, more studies must examine conducting qualitative, in-depth interviews with nursing students, integrating VR apps into several medical courses, and practical skills.

Conclusion

The study concluded that nursing students supported to use of immersive VR through three-dimensional visuals in their anatomy lectures and had a positive perception of virtual reality technology that enhanced their satisfaction and retained and recalled their knowledge. Future generations may find learning more accessible and concepts more concrete with the use of these technologies. Thus, immersive VR is viewed as a complementary/supplemental tool to improve the learning process and outcome. Additionally, a lot of nursing programs have to integrate any new instructional approach that attempts to improve nursing education for learners as well as educators into the curriculum. For examples of these approaches include immersive virtual reality, serious games, mobile applications, simulations, etc.

This study recommended including virtual reality (VR) in the curriculum of several courses including a human anatomy course as a supplementary tool to facilitate and strengthen the learning process. Educators need to think about the benefits of VR in a variety of nursing courses and assist in addressing possible risks including the expense of technology, available space, and VR usage training.

Implication in nursing education

The study will contribute to developing nursing education by inserting innovative technologies such as VR and strengthening a more dynamic, efficient, and technologically progressive learning environment to meet the demands of students and future healthcare professionals. It is also expected to encourage nursing students' learning skills and abilities. Immersive VR may be merged into bioscience courses like physics, anatomy, chemistry, etc., and this study may direct experimental studies exploring whether virtual reality improves students' learning and retention of knowledge. On the other hand, this study promotes more qualitative and quantitative research on student engagement and VR experiences, helping to bridge the knowledge gap between nursing theory and practice regarding nursing students' perceptions of virtual reality technologies and their level of satisfaction, knowledge, and performance. Additionally, clients should be closely involved in the design of immersive VR apps by developers. As a result, developers of VR apps need to promote their attributes and qualify their programs to meet the needs of their users.

Acknowledgements

The authors thankful the Al-Quds Business Center for innovation, technology, and Entrepreneurship (BCITE) at Al-Quds University for providing us with the opportunity to conduct this study and for all of the resources and support they provided.

Author contributions

S.J. was a major contributor in writing the manuscript, conceptualization, and interpreting the data designed for the manuscript. I.N., L.AH., D.M., A.S., R.M., Y.S., and N.F. collected, organized, and analyzed data. All authors read and approved the final manuscript."

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

No datasets were generated or analysed during the current study. No/Not applicable (this manuscript does not report data generation or analysis). Also, No, all of the material is owned by the authors and/or no permissions are required.

Declarations

Ethics approval and consent to participate

Approval from the Scientific and Ethics Research Committees of Al-Quds University was obtained (RESC/2024-22). Participants were informed that filling out a study questionnaire would be considered informed consent, they could withdraw their consent, and that participation in the study was voluntary; they had the right to accept or refuse to participate.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 8 June 2024 / Accepted: 12 August 2024
Published online: 28 August 2024

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