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RESEARCH REPORT

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The effectiveness of immersive virtual reality applications (human anatomy) on self-directed learning competencies among undergraduate nursing students: A cross-sectional study

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Abstract

Technological developments have significantly impacted various aspects of life, most notably healthcare and education. A nursing education shift was required to prepare digital generation. Consequently, nurse educators must adopt innovative approaches to teaching and learning, like incorporating immersive virtual reality (VR) into human anatomy courses to improve students' learning. To examine the influence of immersive VR applications (human anatomy) on self-directed learning (SDL) competencies among undergraduate nursing students. A cross-sectional design was conducted in the health profession's faculty at Al-Quds University among the first year of the nursing program, who were enrolled in an anatomy course ($N = 137$). The Self-Directed Learning Instrument was used, and independent sample *t*-tests were conducted to compare the level of SDL among students who utilized the VR application (Human Anatomy VR). The results showed that 93.9% of the total were approximately 20 years old, and 85.4% were females. 90.5% of participants expressed satisfaction with using the VR application and that it would be beneficial in nursing courses. The average score of SDL for the whole group was 72.03 ± 13.07, and there is a positive significant relationship between SDL and students utilizing VR ($p < 0.001$), between SDL competencies and technological skills ($p = 0.009$), and type of digital tools ($p = 0.049$). The highest coefficient of correlation was related to planning and self-monitoring ($r = 0.918$), and the lowest was related to interpersonal communications ($r = 0.865$). VR is an additional tool for enhancing learning, and nursing students perceive immersive VR technologies positively and prefer using three-dimensional images in their anatomy courses. SDL assists students in identifying learning objectives, barriers, and outcomes through using VR technologies as teaching strategies.

KEYWORDS
anatomy education, extended reality, immersive virtual reality, nursing education, self-directed learning, virtual reality

INTRODUCTION

In the 21st century, technological developments have significantly impacted various aspects of life, most notably healthcare and education.[1] A nursing education shift was required to prepare digital generation of nursing students in complex and developed healthcare settings to provide safe nursing practice and improve patient outcomes,[2] which required science courses as prerequisites for admission, build self-efficacy, encourage independent study, provide activities that meet various learning styles, and incorporate active learning through adopting innovative approaches to teaching and learning.[3-5]

Teaching bioscience courses, such as anatomy, typically taught in the first year of nursing programs, is one of the most challenging and essential aspects of nursing education.[4] These challenges include low student knowledge, high failure rates, an absence of anatomy labs, a faculty shortage of specialized training facilities and simulation equipment, the high cost of anatomic models, and a lack of donors.[6-9] So, nurse educators employ a variety of educational strategies to effectively support students' acquisition of knowledge and comprehension of anatomy concepts and structures.

Traditional anatomy courses for nursing students typically use lab materials made from donated human bodies and organs, PowerPoint slides with illustrations or sketches of anatomical landmarks, and 3D spatial renderings.[10] These methods need infrastructure, curricular time, cooperation, and immersion to meet all learning objectives.[11] As a result, nurse educators are looking for innovative strategies to integrate information technology (IT) into anatomy courses, such as virtual reality (VR), offering an alternative educational experience compared with traditional teaching techniques.[12]

In recent years, the usage of extended reality (XR) systems in nursing education has been on the rise, including virtual, augmented, and mixed reality (VR, XR, and MR, respectively)[13] because it provides several benefits, including the ability to train participants safely and without risk as well as the chance for repetition to help them achieve a certain level of competency and enhance retention.[14]

VR, which is one of the most widely used computer-based technologies that creates a cooperative three-dimensional (3D) environment that immerses users, comprises a head-mounted device that integrates full-body movement into an environment that closely mimics reality in great detail through visual, audio, and motor inputs.[15,16] In anatomy education, VR offers an immersive and distraction-free learning environment, enabling students to imagine and determine anatomical components in three dimensions.[17,18] With the help of the software's built-in educational tools—labeling, underlining, flashcards, and informative tags—it offers each learner a personalized, flexible, asynchronous, and on-demand learning environment. Additionally, users can pre-record interactive sessions and repeat lessons and scenarios as necessary to reinforce understanding and skills. As a result, VR has advantages, but it may not completely replace all aspects of traditional anatomy education. Consequently, VR significantly enhances efficiency and self-efficacy in the learning process and promotes spatial understanding and knowledge retention.[19-21] VR may be an effective strategy used as a supplemental tool alongside traditional method.[22]

According to Knowles, self-directed learning (SDL) is a process where people take control of their education, either on their own or with the assistance of others. They diagnose their learning needs, make plans for their education, identify the individuals and resources they need to learn, choose and implement the appropriate methods of learning, and assess their progress toward their learning objectives.[23] SDL transfers responsibility for learning from a third-party source to the learner, promotes their independence, enables them to regulate their learning via responsibility and self-control, and improves their motivation.[24] It consists of motivation, self-monitoring, and self-management.[25] SDL is an effective form of nursing education that helps students become more knowledgeable and improve the quality of their practice,[26] stay flexible and accessible to change, keep with their practice skills, and increase confidence and professionalism.[27]

Kolb's experiential learning theory and virtual reality

The greater level of conceptual understanding is addressed by Kolb's experiential education theory, which emphasizes the importance of reflecting, comprehending, interacting with, and applying in virtual classrooms, such as VR (McLeod, 2018).[28] Using Kolb's experiential learning theory, learners in nursing gain information from activities in a virtual environment as if they were in real life by facilitating and examining their learning process to achieve objectives and learning outcomes (Tepe et al., 2016).[29]

In the current study, the researcher attempted to apply Kolb's theory based on the student's comprehension of the description, context, and concepts of anatomy, including knowledge of the anatomical structures of various systems, including the musculoskeletal system, and explaining the structural and functional organization of the human body's systems and organs. The researcher used a variety of teaching strategies, including lectures, discussion, and PowerPoint slides, as well as an implemented Immersive VR application (Human Anatomy), until students were able to meet the learning objectives associated with this course in nursing curricula, which included identifying levels of human body organization and describing the structure and function of related human body systems (integumentary, skeletal, muscular, nervous systems), etc. As a result, by explaining the location, structural, and functional organization of body organs and systems about other body structures and systems, defining terms related to the study of human body anatomy and physiology, and identifying the particular prominent characteristics in the structure and function of the different body systems, educators and

students achieve the intended learning outcomes associated with knowledge (cognitive demand).

Hence, to meet the study's objectives and learning outcomes and support Kolb's theory, we ensured that all students who took part in the study took a traditional lecture on the musculo-skeletal system and then used immersive VR applications for the same system to understand conceptualizations, describe and demonstrate the locations of the skeletal and muscle systems, and ensure that their knowledge was retained in comparison to traditional methods. This was achieved by examining students' perceptions of knowledge, satisfaction, and benefits, as well as their ability to self-direct their learning toward utilizing immersive VR applications for human anatomy in anatomy courses.

As technology continues to advance and in light of previous literature, we anticipate that VR will play an increasingly significant role in nursing education, where it can be most beneficial, and we are investigating the impacts of VR-based learning on SDL competencies and on knowledge retention.[12,30,31]

This study aims to examine the influence of immersive VR applications (human anatomy) on SDL competencies among undergraduate nursing students and explore nursing students' perceptions of utilizing VR in anatomy courses.

RESEARCH QUESTIONS

- Do SDL competencies vary among nursing students based on sociodemographic factors such as sex, age, technological skills, grade average in previous courses, place of residence, most digital tool used during course, and internet connection?
- What is the perception of nursing students about their immersive VR engagement?
- Which subdimensions and levels of SDL skills are demonstrated by nursing students while using immersive VR applications?

METHODOLOGY

Study design

A cross-sectional design was utilized. It was used to assess baseline data of nursing students' SDL toward immersive VR. Cross-sectional design is appropriate for studying the status of phenomena at a fixed point in time.[32]

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. Data collection from participants during the anatomy course from March 10 to 17, 2024, was performed by the researcher.

Participants

The whole population of the study was 205 students in the first year of the nursing program who were enrolled in an anatomy course (3 h/week) in the spring semester of the 2023–2024 academic year. The study sample was calculated by applying the sample size formula for estimating proportions, with a 95% confidence level, a margin of error of 0.05, and a population proportion of 0.5.[33] The minimum required sample size was determined to be 134 participants related to formula ($n = z^2 \times p \times (1-p)/e^2$), where p: the population size, e: the margin error, and z: the z-value, extracted from a z-table. Ultimately, 137 students responded to the questionnaire, which was greater than the sample size needed.

Inclusion criteria

All of the first-year nursing students enrolled in the Anatomy course, which is a specialization requirement course in the nursing program at Al-Quds University, in the spring semester 2023–2024 academic year who took the musculoskeletal system chapter in this course (theory) were included. Also, students who attended the VR application (Human Anatomy VR for Institutions) through Meta Quest 2 (Immersive All-in-One VR Headset) were included.

Data collection instruments

Part 1: Sociodemographic information

Sociodemographic characteristics of participants were described, and it was designed by the researcher based on previous literature studies.[1,34] It included questions relating to sex, age, grade average, place of residence, IT skill level, most digital tools used during course work, and if participants have internet connectivity in their place of residence.

Part 2: Students perceptions toward using immersive VR in nursing education

Student's perception toward using immersive VR technology in nurse programs, which was designed by the researcher based on previous literature studies, was described using six Yes or No questions.[1,34] Also, general three open-ended questions were developed by the researcher:

- Describe your experience with the VR human anatomy training in your course.
- How would you compare your VR training with the traditional classroom?
- How did VR training influence your performance on your exam?

Part 3: Self-directed learning instrument (SDLI)

The Self-Directed Learning Instrument (SDLI) is a self-report instrument that was specially developed to measure the SDL of nursing students. It was developed by SF-Cheng[35] and contains 20 items across the four domains of learning motivation (LM, 6 items), planning and implementing (PI, 6 items), self-monitoring (SM, 4 items), and interpersonal communication (IC, 4 items). The respondent is asked to rate each item on a 5-point Likert scale ranging from 1 for "strongly disagree" to 5 for "strongly agree." The value of Cronbach's α for the total scale was 0.916 and for the four domains was 0.801, 0.861, 0.785, and 0.765, respectively.[35] The reliability of the questionnaire was also analyzed using the Statistical Packages for the Social Sciences (SPSS) to obtain Cronbach's alpha value, which was 0.945. This indicated that the questionnaire was highly reliable[36] (see Table 1).

Procedures

After the students attended the Anatomy lecture (Musculoskeletal System Chapter) traditionally taught by PowerPoint slides in a physical classroom, they were told to participate in a demonstration of the musculoskeletal system through VR to achieve learning objectives, including understanding anatomical concepts and displaying musculoskeletal structures. The course is designed to have participation marks based on the students' engagement with the various learning activities.

The researcher obtained approval from the Scientific and Ethics Research Committees and the Chief of the Al-Quds Business Center for Innovation, Technology, and Entrepreneurship (BCITE) at Alquds University to conduct this study in the center, which is equipped with all the immersive VR tools (3D Meta-Quest 2, head-mounts, trackings, show screens, etc.). Over 6 days, all students (137) who attended were randomly divided into 20–25 students daily as an activity that was part of their scheduled course, and this activity could be attempted during their free time so that it did not clash with other courses. Also, every student enrolled their name and university ID through the Whatsapp group to identify their suitable day and time by facilitators.

At the beginning, a teaching demonstration of VR took place, by wearing handheld controllers and a headset (Oculus Quest 2, version 55) in front of participants, and displayed a 10-minute video of the Human Anatomy VR application from the Meta Store (https://www.meta.com/experiences/human-anatomy-vr-for-institutions/3662196457238336/). Then, guided them in the proper use of the application.

Next, in a single-user VR setting, facilitators, who were students in the 4th-level academic year ($n = 5$), under the direction of the researcher, visualized the skeletal system from head to toe with the freedom to walk around and view it from different angles as facilitators pointed to, labeled, and manipulated individual bones such as the skull, vertebrae, ribs, and hip. This was followed by the muscle display, which includes muscles, shapes, and sites, including upper and lower regions. They then allowed students to ask questions that addressed their concerns before beginning their experience.

After that, 25 participants were distributed to 5 facilitators: for each group (5 participants), a facilitator and VR Oculus Quest were assigned. Each participant in the group joined the virtual room through the Oculus Quest 2 and was led through a structured lesson plan for the basic anatomy of a musculoskeletal system, and the participants were then allowed to freely interact with the VR application using the skills they were previously taught. This "free play" session lasted for 10 minutes for individual exploration with continued technical support and access to facilitators for clarification and replicated different maneuvers between participants to obtain the same views and results, pausing for understanding and guidance as needed.

At the end of the training day, each student gave their informed consent after learning the purpose of their participation in the study. In the first section, they were required to fill out demographic information by age, sex, grade average, etc. In the second section, they were asked to express their perceptions about utilizing VR applications in the anatomy course and other courses in the nursing curriculum through responses to yes-or-no questions. Also, they were required to complete the last section's selections, which showed a 5-point Likert SDL scale toward utilizing the immersive VR (Human Anatomy VR) application in the anatomy course. The time frame for this was March 10–17, 2024. One week after the end of this study, the researcher (educator) conducted an exam for this course related to the musculoskeletal system to know whether students obtained knowledge and benefited from this experience or not (see Figure 1).

TABLE 1 Reliability of SDLI.

Item	Cronbach's alpha	No. of items
LM	0.815	6
PI	0.885	6
SM	0.797	4
IC	0.825	4
Total	0.945	20

Ethical considerations

Before data collection, approval from the Scientific and Ethics Research Committees of Al-Quds University was obtained (RESC/2024-7). 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 that filling out

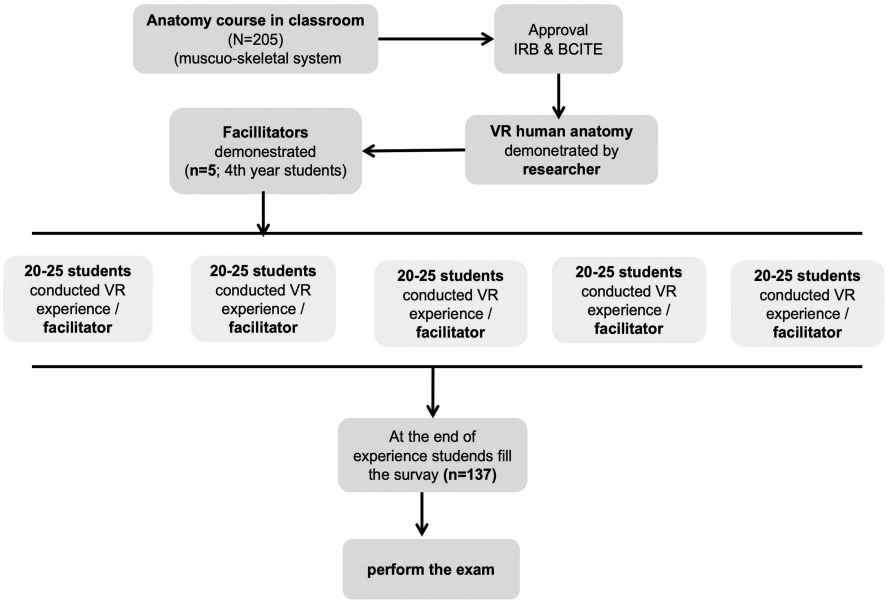

FIGURE 1 Procedure of study.

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.[37] 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. Kuder–Richardson-20 (KR-20) was used to assess the reliability of six Yes or No questions according to students' perceptions of using immersive VR technology in nursing programs. Qualitative data were analyzed using descriptive thematic analysis, which involved reading and examining the interview transcript to identify measure themes such as exam performance, knowledge, satisfaction, and engagement. Furthermore, independent sample *t*-tests were conducted to compare the level of SDL among students who utilized the VR application (Human Anatomy VR), while a one-way analysis of variance was used to test mean differences for variables with two or more categories. A *p*-value less than 0.05 was considered significant.

RESULTS

Students' sociodemographic characteristics

A total of 137 first-year undergraduate students in a nursing department participated in the study. The results showed that 128 participants, or 93.9% of the total, were below 20 years. Out of the 137 participants, 85.4% were female. Fifty-six participants (40.9%) used mobile phones as the most common digital tool, and 57.7% possessed basic technological skills. The demographic information for all participants is provided in Table 2.

TABLE 2 Students' demographics data ($n = 137$).

Variable	Category	*N* (%)
Gender	Male	20 (14.6)
	Female	117 (85.4)
Age (years)	<20	128 (93.4)
	20–24	9 (6.6)
Average	70%–79%	19 (13.9)
	80%–89%	83 (60.6)
	90%–100%	35 (25.5)
Place of residence	City	89 (65.0)
	Village/camp	48 (35.0)
Technology skills	Limited	43 (31.4)
	Basic	79 (57.7)
	Advanced	15 (10.9)
Most digital tool used during course work	Computer	45 (32.8)
	Mobile phone	56 (40.9)
	Tablet	29 (21.2)
	None	7 (5.1)
Internet connectivity in place of residence	Yes	132 (96.4)
	No	5 (3.6)

Students' perceptions toward using immersive VR in nursing education

The reliability for the six items that describe students' perceptions toward using immersive VR in nursing programs in this study was 0.887. This KR20 value indicates high internal consistency (>0.70) according to Wallen and Fraenkel.[38]

Table 3 shows that 96.4% of participants agreed that using VR technology in the nursing program would be beneficial; 90.5% of

TABLE 3 Students' perceptions toward using VR in nursing education ($n = 137$).

Items	Category	*N* (%)
Have you previously played virtual computer games?	Yes	78 (56.9)
	No	59 (43.1)
Have you experienced VR before?	Yes	63 (46.0)
	No	74 (54.0)
Are you satisfied with your VR-based learning experience?	Yes	124 (90.5)
	No	13 (9.5)
Do you think you gain knowledge in nursing courses when using VR applications?	Yes	74 (54.0)
	No	63 (46.0)
Do you think the use of VR technology in nursing would be beneficial?	Yes	132 (96.4)
	No	5 (3.6)
Do you suffer from motion sickness while using VR application?	Yes	54 (39.4)
	No	83 (60.6)

them expressed satisfaction with using the immersive VR application (Human Anatomy VR); and 60.6% of them reported not experiencing motion sickness while using it. Even though half of them had never used VR technology before, they attest that it is a useful tool for gaining knowledge in nursing courses.

The researcher also inquired about students' perspectives on the use of VR apps in human anatomy courses. "I found that using the VR program in human anatomy helped me understand the musculoskeletal lesson the best," a student said in response according to *knowledge*. "It's hard to learn and remember things without experience in real life. VR proved to be the most suitable substitute in terms of adapting to my learning style." Other students also shared their thoughts on how well they *performed on the exam*: "I was satisfied with my exam performance when I identified the questions that linked to the lecture on the musculoskeletal system; right away, I could visualize and recall every bone and muscle. Virtual reality technology, in my opinion, is a useful tool for information retention over time. I propose incorporating this technology into nursing curricula in courses related to human anatomy and other courses." Regarding *the VR engagement element* as well, "I like it because it made things possible for me to accomplish and engage with it that I couldn't do with traditional lectures." (see Figure 2).

For example, "Walking within the spinal column and seeing the precise locations of the bone markers, might help one better understand how things are arranged spatially, it's also possible to add more structures, like vertebrae, and see where they fit in."

Subdimensions and levels of SDL skills

Table 4 shows that the average score of SDL for the whole group was 72.03 ± 13.07 out of 100. The averages were similar across the subdomains. The average motivation subdomain is 22.19 ± 4.28, planning (21.04 ± 4.24) out of 30, SM (14.33 ± 2.94), and IC (14.45 ± 2.99) out of 20.

FIGURE 2 Student engagement via VR.

TABLE 4 Students' averages of the total self-directed and subdomains of the learning competencies toward using VR ($n = 137$).

Item	Minimum	Maximum	Mean	*SD*
LM	11.00	30.00	22.19	4.28
PI	10.00	30.00	21.04	4.24
SM	7.00	20.00	14.33	2.94
IC	6.00	20.00	14.45	2.99
Total	41.00	100.00	72.03	13.07

Independent samples *t*-tests were conducted to test for statistically significant differences in means of the total scales and subscales for each perception item in Table 3. No statistically significant difference was observed (tables not shown).

Table 5 shows the correlations between the total SDL scale and the four scale subdomains. Generally, the analysis showed a positive and significant relationship between SDL and students utilizing VR ($p < 0.001$). The highest coefficient of correlation was related to planning and SM ($r = 0.918$), and the lowest was related to ICs ($r = 0.865$).

TABLE 5 Correlation SDL competencies among students who utilized VR.

		Motivation	Planning	SM	Communication
SDL	Pearson correlation	0.908[a]	0.918[a]	0.918[a]	0.865[a]
	Sig. (2-tailed)	<0.001	<0.001	<0.001	<0.001
	N	137	137	137	137

[a]Correlation is significant at the 0.01 level (2-tailed).

SDL skills among nursing students based on sociodemographic factors

The results in Table 6 show a positive and significant relationship between SDL competencies and technological skills ($p=0.009$). The average score increased as the technological skill level increased from 67.79 among students with limited to no technological skills to 79 among students with advanced skills, $p<0.01$. The type of digital tool mostly used during coursework was statistically significant and related to SDL, $p<0.05$. Students who mostly used the mobile phone in their coursework had a lower score (69.01) than students who used computers (74.57) than students who mostly used tablets (75.27) ($p=0.049$).

The differences between the means of each subscale were also examined by background characteristics (tables not shown). Significant relationships were found between motivation, SM, communication categories, and technological skills ($p=0.022$, $p=0.010$, and $p=0.005$, respectively). Also, the relationship between motivation and communication categories and most digital tools used during coursework was statistically significant ($p=0.034$, $p=0.043$). Furthermore, a positive and significant relationship exists between the planning category and grade ($p=0.023$).

TABLE 6 Means and *SD*s of the total SDL competencies for using VR and their demographic characteristics.

Variable	Category	*M* (*SD*)	*F*	*p* Value
Gender	Male	75.55 (15.64)	1.701	0.194
	Female	71.43 (12.55)		
Age (years)	<20	72.23 (13.19)	0.029	0.506
	20–24	69.22 (11.49)		
Average	70%–79%	65.89 (10.67)	2.524	0.084
	80%–89%	73.22 (13.01)		
	90%–100%	71.54 (13.77)		
Place of residence	City	71.46 (13.81)	0.491	0.485
	Village/camp	73.10 (11.62)		
Technology skills	Limited	67.79 (12.79)	4.887	**0.009***
	Basic	73.02 (11.84)		
	Advanced	79 (16.56)		
Most digital tool used during course work	Computer	74.57 (12.52)	2.682	**0.049***
	Mobile phone	69.01 (12.99)		
	Tablet	75.27 (13.76)		
	None	66.42 (8.30)		
Internet connectivity in place of residence	Yes	71.93 (12.94)	0.290	0.632
	No	74.8 (17.62)		

*$p<0.05$.

DISCUSSION

According to the study's findings, first-year nursing participants were mostly female, under 20 years, and skilled with technology—as could be expected given their generational background.[39] Additionally, even though the students had never encountered VR in a nursing education program, they tended to play virtual computer games as typical of Generation Z. This is in line with a study conducted by Hernandez-de-Menendez et al.[40] that showed Generation Z is prepared to utilize technological developments in education.[40] All these characteristics are beneficial for the adoption of immersive VR technologies in nursing education, allowing the students to gain the required confidence and skills in a safe environment without any risk to the patients.[1,41]

Students' perceptions toward immersive VR application

This study examined nursing students' perceptions of using immersive VR applications in anatomy courses. It found that using VR applications improved students' knowledge acquisition in the course and reflected their satisfaction with VR-based learning. These study findings were presented after students took human anatomy in the muscular-skeletal system through traditional lectures. They then used VR within the same system to improve and retain their knowledge by visualizing the spatial relationships between anatomical structures in three dimensions and identifying the concepts and elements of human anatomy structures. This concurs with studies by Chen et al.[42] and Brown et al.[43], which demonstrated that effective student feedback prefers the use of this educational strategy as a supplemental tool in the study of human anatomy, enabling students to recognize the spatial relationship between anatomical structures in a special 3D setting[42,43] and enhancing the link between theory and practice by encouraging experiential learning by doing.[44,45] So, allowing nursing students to engage in virtual reality-based education improves their learning outcomes and to achieve cognitive learning objectives, by identifying and analyzing concepts,[46,47] through individual

exploration visualizing the skeletal system from head to toe with the freedom to walk around and view it from different angles, and muscular displays involving muscles, shapes, and sites, including upper and lower regions, allowing students to immerse and interact with learning virtual environment.

Additionally, this study indicated that VR helped students gain knowledge and retain it through memorizing the content and recalling the information, which was noticed while performing their exam after the VR experience. In addition, it increased their performance compared to traditional lecture exams before the VR experience. These findings support the idea that VR is an innovative and useful tool for nursing education, as it assists students in gaining in-depth knowledge of the learning objectives and enhances their academic performance.[48] It also confirms their understanding and perceptions of anatomical spatial knowledge and skills, which may be linked to a better comprehension of human anatomy.[22,43,49,50]

Furthermore, the majority of students believe that VR technology is beneficial and useful in the nursing field, which is in agreement with research conducted by Aydın[51], Huang et al.[52], Moro et al.[19], and Stepan et al.[53] These studies found that immersion VR was a significant predictor of the perceived usefulness of a VR application for learning about body systems, especially for those with minimal knowledge, through the use of visual representations that enhance comprehension of complex concepts in an educational context and make academic subjects more accessible and engaging.[19,51,52,53] As a result, VR may bridge the knowledge gap between theory and practice, especially when it comes to enhancing learning, encouraging usage, and fostering an appreciation for the use of 3D images in anatomy education.[6,49]

Most students in this study who used VR applications in anatomy lessons reported feeling comfortable doing so. They also reported that they did not experience motion sickness when exposed to immersive VR, which is similar to the result of studies by Huygelier et al.[54] and Fernandes and Feiner[55] which found that motion sickness is more common in extreme VR gaming—which involves "shooting" and "falling"—than in using VR for educational purposes that depend on newer approaches to VR design.[54,55] Because anatomy-specific concepts could be better explored through visualization, VR is one alternative to improve learning in nursing education.

SDL skills during utilized immersive VR

This study used VR technology to investigate how students perceived their abilities for SDL. The results showed that these students had a high level of SDL skills (72.03 ± 13.07). These findings are consistent with research conducted by Tekkol and Demirel[56] and Yilmazsoy and Kahraman[57], who observed that self-directed learners participating in distance or online education tended to demonstrate particular characteristics, including advanced communication skills, motivation, curiosity, willingness to take responsibility for learning, and ability for self-evaluation,[56,57] confirming that learning environments and educational strategies like immersive VR have an impact on the ability of learners for SDL.[58]

In this study, students showed a high level of motivation (22.19 ± 4.28) and a positive correlation ($r = 0.908$) toward using VR applications. These findings are consistent with studies by Thompson et al.[59], Hasgören and Seçkin[45], and Karagülle and Berkant (2022), indicating that students appeared ready for innovative technologies like VR. They also showed motivation, self-control, and a willingness to learn, which is linked to the immersive and unique nature of VR, promoting experiential learning by doing.[45,59,60] Additionally, via repeated exposure to content and essential clinical skills, VR apps motivate nursing students to engage in virtual practice and acquire procedural skills, reinforcing the link between theory and practice among students.[44]

The results indicate a positive correlation ($r = 0.918$) between SDL skills and planning, implementation, and SM, highlighting the fact that SDL is a meta-cognitive skill that many students need to develop their knowledge, gain an essential understanding of anatomy, and further their education. Similar studies by Falk et al.[61], Paas and Sweller[62], and Chang et al.[63] concluded that PI theory and practice into practice helps students' learning of instructional content and improves their readiness for clinical practice.[61-63] For this reason, providing nursing students the opportunity to receive VR-based learning improves their learning outcomes.[47]

Students' involvement fosters the idea that they can all utilize technology to advance their abilities in SM.[64] As a teaching method, the use of VR features like lighting, audio, special effects, and animation systems allowed students to place themselves within the game and engage freely in a realistic and standardized way. This was found to be significant for SM, motivation, and learning.[65,66]

In terms of IC skills, VR provides a pleasant environment that encourages empathy and understanding; it fully engages trainees and delivers more transferable knowledge; students can express their ideas, feel in control, complete tasks, and interact with others, increasing the probability that they will enjoy and participate in activities in the virtual world before applying them to the real world.[67-69] In this study, we have found a positive connection ($r = 0.865$) for IC; however, this correlation is lower than those observed for motivation, PI, and SM. This can be explained by the students' initial interest in and curiosity about VR applications,[70] as well as their later realization of unrealistic expectations and anxiety with the technology limitations of the VRs. Similar experiences were reported by Borja-Hart et al.[71] and Kuntze et al.[72], who noted that the VR application occasionally misinterpreted speech and did a poor job of speech recognition, as well as primary communication barriers like shyness, fear, and language.[71,72] Despite this, the students in the study had a clear objective for the VR human anatomy practice, which allowed them to participate, develop their professional communication skills, and share their authenticity of emotion. This aligns with studies conducted by Adefila et al. (2018)[46] and Peddle et al.[73], which found that students are used to learning objectives based on cognition, which requires them to recognize, anticipate,

or analyze theories and concepts. These studies also confirmed the significance of empathy, authenticity of emotion, and variability of VR design in replicating real-life interactions for effective teaching.[46,73] Furthermore, VR applications have the ability to offer additional free-text clarifications when necessary, thereby contributing to an increased level of students' communication. These findings align with those of Peddle et al.[73], who demonstrated the beneficial effects of VR interactions on students' development of particular communication skills.[73]

Students' demographic toward SDL skills

In today's society, when social and contextual circumstances are changing quickly, particularly in the digital era, SDL is an essential skill for individuals to possess.[74,75] Because of the digital generation's comfort and competence with technology, the results demonstrated a positive and significant association between technical abilities and SDL capacities ($p=0.009$). In light of this, VR programs can be considered a highly beneficial approach. This is consistent with studies by Nasri and Mydin[76] and Zheng[77] that demonstrated the way students used technical skills to enhance learning and develop SDL skills in a SDL environment.[76,77]

Since 21st-century students are more likely to study and develop and require the use of digital tools to become digitally competent, today's educational institutions must become more adaptable, intelligent, and flexible. Therefore, it is essential to have an in-depth understanding of their preferences for utilizing digital devices in learning environments to encourage their interest in participating in SDL activities.[78-81] In this study, the results indicated that the most feasible digital devices to carry out learning activities and access learning systems associated with SDL were statistically significant ($p=0.049$), and it showed that students who used computers or laptops performed better on SDL than students who used mobile phones.[82-84] Students' opinions of mobile learning were generally favorable, although they showed some resistance when it came to using it, and many stated worries about the lack of immediate support in these types of learning environments.[85]

Furthermore, planning is one of the SDL competencies and is associated with knowing students' objective learning toward utilizing VR and being mature enough to be accountable for their learning, and the results in this study revealed a positive and significant correlation ($p=0.000$). It is also required of nursing students to have SDL skills to continue lifelong learning, as SDL is considered an adult learning approach.[86]

LIMITATION OF STUDY

Al-Quds University nursing students who enrolled in the anatomy course participated in the study, which has limitations due to its small sample size, specific geographical area, and descriptive technique. However, there are limitations to generalizing the findings. The current study was exploratory, and it aimed to investigate how nursing students perceived SDL toward immersive VR application in the nursing curriculum as well as their thoughts on adopting VR in nurse education. Consequently, more studies must look at conducting qualitative in-depth interviews with nursing students, incorporating longitudinal or experimental designs, including baseline measurements and control groups, to more rigorously evaluate the specific impact of VR interventions, and integrating VR apps into several medical courses and practical skills.

IMPLICATIONS OF NURSING EDUCATION

The study contributes to improve nursing education by introducing innovative technologies such as VR and fostering a more dynamic, efficient, and technologically advanced learning environment to fulfill the demands of students and future healthcare professionals. It is also anticipated to enhance nursing students' SDL skills, which are crucial in the nursing curriculum. Immersive VR may be integrated into bioscience courses like physics, anatomy, chemistry, etc., and this study may direct experimental studies exploring whether VR enhances students' learning and retention of knowledge. On the other hand, this study promotes more quantitative and qualitative research on student engagement and VR experiences, helping to bridge the knowledge gap between nursing theory and practice regarding nursing students' perceptions of VR technologies and their level of satisfaction, SDL skills, 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 enhance their features and modify their programs to meet the needs of their users.

CONCLUSIONS

The study concluded that nursing students perceive VR technologies positively and prefer using 3D images in their anatomy courses. These technologies could help make concepts more concrete and make learning easier for future generations. Immersive VR is, therefore, seen as a supplement or additional tool for strengthening learning. Furthermore, many nursing programs incorporate SDL into their basic learning curriculum. By implementing appropriate instructional practices to promote successful learning, SDL includes students in identifying learning objectives, barriers, and outcomes and seeking support. Additionally, it was shown that students possessed high levels of motivation, PI, SM, and IC skills. Consequently, the study offers important new information for the future design of learning approaches.

This study recommended the incorporation of VR into the curriculum, which could be delivered as a supporting aid that contributes to better visualization of learning material. Educators must consider the value of using VR across diverse nursing curricula and

help address potential threats such as technology costs, space, and training in VR use.

AUTHOR CONTRIBUTIONS

Samar Thabet Jallad: Conceptualization; investigation; methodology; supervision; validation; writing – original draft; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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