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Nursing students' engagement and experiences with virtual reality in an undergraduate bioscience course

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Abstract

Objectives: The challenges of bioscience courses such as anatomy and physiology in nursing education are well documented. Virtual reality has recently become accessible and may support student engagement. The purpose of this project was to describe students' engagement and experiences with virtual reality in a first-year nursing course on anatomy, physiology, and health assessment.

Methods: We used a cross-sectional design and collected both quantitative and qualitative data. The Exploratory Learning Model guided our work.

Results: Students perceived their engagement to be higher in virtual reality compared to other teaching methods. Their experiences were positive with students reporting that they found it easy to use, it helped their learning, and they recommended more of it.

Conclusions: Virtual reality is an accessible tool for supporting student engagement. The Exploratory Learning Model is a useful conceptualization for integrating virtual reality into a course. Future research on the relationship between virtual reality and learning achievements is warranted.

Keywords: bioscience; exploratory learning model; nursing education; virtual reality.

Introduction

Bioscience courses such as anatomy and physiology are foundational to nursing education (Montayre, Dimalapang, Sparks, & Neville, 2019; Perkins, 2019). Unfortunately, they are also considered the most challenging and often result in students not learning, or retaining, knowledge required for safe nursing practice (Jensen, Knutstad, & Fawcett, 2018; Jordan, Davies, & Green, 1999; McVicar, Andrew, & Kemble, 2015). Efforts to improve bioscience education are not new, but with research now linking a lack of bioscience knowledge to poorer patient outcomes, the need for improvements are clear (Bakon, Craft, Christensen, & Wirihana, 2016; Fawcett, Waugh, & Smith, 2016; Perkins, 2019).

Researchers have suggested several supports for bioscience learning in nursing including requiring science courses as admission prerequisites, supporting post-secondary study skills, developing science self-efficacy, encouraging independent study, offering activities to appeal to different learning styles, and incorporating active learning (Bakon et al., 2016; Evensen, Brataas, & Cui, 2020; Johnston et al., 2015; McVicar et al., 2015). Educators in medicine have recently suggested technological approaches such as virtual reality (VR) be integrated into bioscience courses as a means of supporting student learning (Erolin, Reid, & McDougall, 2019; Izard, Juanes Méndez, & Palomera, 2017; Moro, Štromberga, Raikos, & Stirling, 2017). VR has potential to encourage independent learning, appeal to different learning approaches, improve self-confidence, and is a form of active learning (Chang & Weiner, 2016; Farra, Smith, & Ulrich, 2018; Johnson-Glenberg, 2018; Pulijala, Ma, Pears, Peebles, & Ayoub, 2018;

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Williams, Jones, & Walker, 2018). However, VR is relatively new in nursing education and little is known about how nursing students may engage with such technology within bioscience courses. For example, authors of two systematic reviews and one scoping review that recently explored VR in nursing education did not report on any studies that examined VR as a teaching tool for bioscience courses in nursing (Fealy et al., 2019; Foronda, Fernandez-Burgos, Nadeau, Kelley, & Henry, 2020; Rourke, 2020). To that end, the project described here seeks to explore nursing student engagement with VR in a bioscience course.

Student engagement is important for learning (Foronda et al., 2020) and necessary for integrating VR into teaching (Davies, Crohn, & Treadgold, 2018). Therefore, an understanding of how nursing students perceive their engagement with VR and experience the technology can inform future initiatives for how VR may be integrated within bioscience courses and nursing curricula. Further, such knowledge can inform experimental research exploring if VR improves student knowledge acquisition and retention. This article describes the findings from a small project undertaken to integrate and explore VR within an anatomy, physiology, and health assessment course in nursing. We present quantitative and qualitative findings exploring student engagement and experiences with the VR. As well, we describe how VR was embedded within the course.

Literature review

Bioscience in undergraduate nursing education

Bioscience courses focus on topics such as anatomy, biochemistry, and physiology. Often situated in the first year of nursing programs, they are considered to be foundational to nursing education by both teachers and students (Jensen, Knutstad, & Fawcett, 2018; McVicar, Andrew, & Kemble, 2014; Taylor, Ashelford, Fell, & Goacher, 2015). Unfortunately, despite high satisfaction, students consider these courses exceptionally challenging and often experience poor knowledge acquisition and high failure rates (Jensen et al., 2018; Jordan et al., 1999; McVicar et al., 2014, 2015; Taylor et al., 2015). Multiple factors have been attributed to this 'bioscience problem' in nursing education as well as approaches to address it (Jensen et al., 2018; Jordan et al., 1999; McVicar et al., 2015).

McVicar and colleagues have published two widely cited integrative reviews related to bioscience education in nursing (McVicar et al., 2014, 2015). They found several factors predictive of bioscience learning in nursing including prior academic achievement in science courses (high school or otherwise), perceived relevance to clinical practice, perceived time deficiency to study bioscience content, self-efficacy in science, lack of pre-reading, and poor attendance in lectures (McVicar et al., 2015). To inform curricular changes, McVicar et al. (2015) offered several recommendations including ensuring admission prerequisites in science courses, focusing on developing student academic skills, and raising student self-efficacy in science. In an earlier review they focused on curricular interventions to improve bioscience learning in nursing and reported that adjunct online supports aimed at student learning or self-efficacy show promise (McVicar et al., 2014). Although, the field would benefit from more rigorous study designs with a focus on formative learning both within bioscience courses and the senior years of nursing programs, the authors noted the challenge of conducting evaluative research in this area (McVicar et al., 2014).

Findings from the McVicar reviews align with a recent review by Jensen (Jensen et al., 2018) who included qualitative and quantitative studies to explore why nursing students find bioscience courses challenging. Similar to McVicar and colleagues (McVicar et al., 2015), they found that students do well when they are prepared and find the content relevant to practice. The latter finding aligns with another systematic review on active learning in bioscience courses which reported that learning can be achieved more effectively if teaching involves active learning such as interaction and engagement (Bakon et al., 2016).

Furthermore, in a recent study from Norway involving 57 first year nursing students, Evensen and colleagues found that independent study was found to be significantly correlated with higher anatomy and physiology grades (Evensen et al., 2020). This aligns McVicar et al. (2014) finding that adjunct supports show

promise for supporting basic science acquisition and Jensen et al. (2018) finding that students who are well prepared and engage with content achieve higher academic outcomes.

Teaching and learning bioscience content in nursing education are complex endeavors and there are no simple solutions for improvement. Attempts to support students to independently engage with bioscience content in addition to lecture-based delivery shows promise. Likewise, efforts to develop student academic skills and self-efficacy are supported. VR has been used in bioscience courses in medical education (Erolin et al., 2019; Izard et al., 2017; Moro et al., 2017). It has potential to encourage independent learning, appeal to different learning approaches, improve self-confidence, and is considered a form of active learning (Chang & Weiner, 2016; Farra et al., 2018; Johnson-Glenberg, 2018; Pulijala et al., 2018; Williams et al., 2018). In the next section, we define and review literature on VR as a teaching tool in post-secondary education nursing education specifically.

Defining virtual reality

The term VR has been defined in many ways. Kardong-Edgren, Farra, Alinier, and Young (2019) recently recommended definitions include a level of *presence* and *immersion*. Presence refers to the feeling of being in an environment generated naturally or artificially. Immersion refers to the actions available within an environment that allow one to interact with and perceive the environment (e.g., looking up to view the underside of an object above) (Kardong-Edgren et al., 2019). Actions are integrated into the perceived environment by wearing, for example, a head-mounted display, headphones, and arm-tracking devices (Kardong-Edgren et al., 2019; Moro et al., 2017). In the project reported here, VR refers to a high level of immersion whereby the equipment creating the virtual environment is a head-mounted device using visual, auditory, and motor stimuli to create an environment that closely replicates reality in great detail while integrating full-body movement (Kardong-Edgren et al., 2019). The result is a high level of presence and immersion. This definition of VR is aligned with Foronda et al. (2020) recommendation to reserve the term VR to refer only to immersive experiences.

Virtual reality as a teaching tool in post-secondary education

Authors generally agree that VR first emerged in the 1960s, became commercially viable in the late 1980s, and experienced a surge of interest through the 1990s (Cipresso, Giglioli, Raya, & Riva, 2018; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). Recently, technological advances related to cost and immersive capabilities have positioned it as an affordable and attractive teaching and learning tool for educators (Johnston, Olivas, Steele, Smith, & Bailey, 2018; Kardong-Edgren et al., 2019; Kavanagh, Luxton-Reilly, Wuensche, & Plimmer, 2017; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). While affordability is relative to equipment, authors predict advances will make VR increasingly affordable in the coming years, thus resulting in its adoption and prompting calls for research into VR as an educational tool (Foronda et al., 2020; Radianti et al., 2020).

Two recent systematic reviews on VR in higher education (Kavanagh et al., 2017; Radianti et al., 2020) have reported positive findings. Kavanagh et al. (2017) published a systematic review on how and why educators use VR in their teaching, and the limitations they experienced. They defined VR broadly and analyzed findings from 99 articles. None of the studies were from nursing; however, one described the use of VR to teach anatomy to medical students but did not evaluate the outcomes (Falah et al., 2014). The review authors reported reasons for using simulation included increased immersion and increased learner motivation. Barriers included software usability, hardware design, and cost. More recently, Radianti et al. (2020) conducted an extensive systematic review on how VR has been studied and applied in higher education. They used a narrower definition than Kavanagh et al. (2017) and analyzed findings from 38 articles, including two from nursing, and found VR research is primarily developmental, largely atheoretical, and mostly focused on learner experience as opposed to knowledge and skill acquisition. Similar to reviews on bioscience education in nursing, they called for experimental research examining learning outcomes. The lack of experimental studies evaluating interventions to support VR in education using

objective learning outcomes speaks to the challenge of conducting evaluative research using such outcomes—a point also identified by McVicar et al. (2014) related to bioscience education.

Virtual reality as a teaching tool in nursing education

Recently, two systematic reviews (Foronda et al., 2020; Rourke, 2020) and one scoping review (Fealy et al., 2019) have examined VR and nursing education. Foronda et al. (2020) reported virtual simulation appears to positively impact learning outcomes. Interestingly, they classified self-reported engagement as a learning outcome because they conceptualized engagement as a necessary precursor to learning, stating that learning occurs best when students are engaged (Foronda et al., 2020). While such an approach is not universally agreed upon (McVicar et al., 2014), engagement is worth considering as a component of learning. However, none of Foronda et al. (2020) included studies examined immersive VR and engagement specifically and instead all aligned with a broader concept of virtual simulation. Specifically, studies that reported on engagement focused on virtual environments where students navigated using a third person perspective (e.g., avatars) to complete clinical scenarios or make clinical decisions (Burke, 2017; Foronda, Hudson, & Budhathoki, 2017; Fowler et al., 2018; Liaw, Chan, Chen, Hooi, & Siau, 2014; McCallum, Ness, & Price, 2011; Verkuyl, Romaniuk, & Mastrilli, 2018). Such forms of virtual simulation are not considered immersive (Foronda et al., 2020; Kardong-Edgren et al., 2019). The lack of studies examining nursing student engagement with immersive VR represents a gap in the literature as engagement is believed to be an important precursor to effective learning (Foronda et al., 2020). Further, only two studies in the Foronda et al. (2020) review examined bioscience education and neither used immersive VR or examined student engagement (Aebersold et al., 2018; Kaveevivitchai et al., 2009).

Taking a narrower approach, Rourke (2020) reviewed studies comparing VR to traditional simulation for learning psychomotor skills. VR was defined as an immersive experience where a user takes a first-person viewpoint using a headset device and interacts with a computer-generated environment. Rourke (2020) concluded that compared to traditional simulation, students who learn psychomotor skills using VR performed favorably for post-test knowledge scores, cognitive gains, skills performance scores, and skill success rate. Moreover, in a scoping review of the application and integration of immersive VR in nursing and midwifery, Fealy et al. (2019) only located two articles—one being a concept development study on how VR could be used in nursing (Kilmon, Brown, Ghosh, & Mikitiuk, 2010) and the other an evaluation of an immersive VR game aimed at teaching urinary catheterization (Butt, Kardong-Edgren, & Ellertson, 2018). They concluded that VR can engage students in learning procedural skills and shows promise for other applications in nursing education. None of the studies included in either review (Fealy et al., 2019; Rourke, 2020) were focused on bioscience teaching or learning in nursing.

Despite the challenges, understanding biosciences is foundational to nursing care. Evidence supports several strategies for improving bioscience learning in nursing. Some strategies that show promise include providing opportunities for students to engage with bioscience content outside of lectures, raising student self-efficacy, making content relevant to practice, and teaching using active learning principles. VR can help accomplish these approaches. However, there is limited research on VR as a teaching tool for bioscience content in nursing. Furthermore, we could find no literature examining nursing student engagement with VR in a bioscience context. Ensuring student engagement is considered a precursor to learning and therefore should be examined.

To support students in a bioscience course we undertook a small project implementing and exploring the usefulness of VR. Our guiding questions were:

- (1) How do nursing students perceive their engagement with VR?
- (2) How do nursing students experience VR in a bioscience course?

In undertaking this work we aimed to inform future decisions about adopting VR within our curriculum. To address calls for the use of theory in VR integration (Radianti et al., 2020), we used the Exploratory Learning Model (ELM) to guide our work.

Figure 1: The exploratory learning model.

The exploratory learning model

The ELM is an extension of Kolb’s experiential learning model (Kolb, 2014) and consists of five elements: experience, exploration, reflection, abstraction, and testing (de Freitas & Neumann, 2009) (Figure 1). The ELM extends Kolb’s model in two ways. First, it introduces *exploration* to capture the active and autonomous nature of learning in virtual environments. Second, it re-conceptualizes *experience* as referring to both real and virtual environments, thus, suggesting that experiences in virtual environments combine with those occurring in real-world contexts. Conceptualizing learning using ELM supports the use of VR to enhance student engagement. Improved student engagement stems from the ability to create more immersive learning opportunities that afford the learner greater control to experience and explore aspects of a VR environment (de Freitas & Neumann, 2009). Likewise, the use of VR allows educators to integrate environments into teaching that would otherwise be inaccessible. Reflection on experiences and explorations can then lead to the formation of abstract concepts amenable to testing in both real-world (i.e., practice labs) and virtual experiences (i.e., VR sessions). We used ELM as a guide for how VR would be applied in our course. Specifically, we envisioned learners using VR to experience and explore body systems and, thus, enabling the formation of abstract concepts that could be tested in health assessment labs. Further, we used concepts from the model to make sense of our qualitative findings.

Note: This figure illustrates the Exploratory Learning Model. Adapted from de Freitas and Neumann (2009). The use of ‘exploratory learning’ for supporting immersive learning in virtual environments. *Computers & Education*, 52(2), 343–352. <https://doi.org/10.1016/j.compedu.2008.09.010>. Copyright covered under STM agreement.

Methods

Design

We used a descriptive design (Polit & Beck, 2004) to measure how students perceived their engagement with the VR sessions and conventional content analysis (Hsieh & Shannon, 2005) to explore their experiences.

The course

The university where this project was conducted offers a three- and four-year Bachelor of Science in Nursing Program. In both programs students must complete a three-credit first-year course on anatomy, physiology, and health assessment. Each week students attend a 3 h anatomy and physiology lecture, a 1 h health assessment lecture, and a 2 h practical health assessment lab. Content is organized by body system and sequenced across lectures and labs. Course requirements included four exams in the anatomy and physiology section, three exams in the health assessment section, and two observed structured clinical evaluations (OSCEs) in the health assessment labs. Combining a bioscience course with health assessment was done to make content relevant to practice. Class size was 205 students with labs being 16–24 students.

Integration of virtual reality

We added two 1 h VR sessions during the 2 h weekly health assessment labs to help student's link bioscience content to nursing practice. The VR sessions were four months apart and focused on the cardiovascular and gastrointestinal system. Students visited the VR lab in groups of 8–14 students. Each student had an opportunity to use the VR system consisting of an Oculus Rift Headset, two Oculus Rift Sensors, and a pair of Oculus Touch controllers. The Oculus hardware provided sensory, motion, and hearing stimuli to fully immerse users. A desktop computer powered the equipment. Total hardware costs were ~\$4,000 CAD. Free Sharecare VR software created three-dimensional environments of the cardiovascular and gastrointestinal system (e.g., peristalsis of the intestine). Students not using the VR equipment observed what the VR user was seeing via a monitor. Using the VR hardware and software, students were able to immerse themselves in the virtual environments to explore and experience anatomy and physiology of the two selected body systems. They examined the anatomy of the systems by zooming in and out on different structures (e.g., opening and closing of heart valves, peristalsis of digestive system). A lab instructor was physically present during the VR sessions to facilitate. The instructor demonstrated the equipment and guided students as they explored the two body systems. Additionally, they applied labels to structures and linked what the students were viewing to assessment findings encountered in practice. VR equipment was available outside of class and lab time and students were encouraged to access it to help engage with content and prepare for lectures. Technical support was available from the university staff.

We used the ELM (de Freitas & Neumann, 2009) to sequence the learning experience and conceptualize how the VR sessions may contribute to student engagement and, presumably, learning. Students attended the lectures on anatomy, physiology, and health assessment prior to attending the VR sessions. Thus, within the VR sessions, they were able to experience and explore aspects of the cardiovascular and gastrointestinal systems in a manner that could reinforce what they previously learned, but also to fill gaps in their understanding (de Freitas & Neumann, 2009). Afterward, during the health assessment labs, the individualized experiences and explorations that occurred within the VR labs could be combined with the real-world practice lab settings to provide opportunities for further exploration, and/or reflection and testing. Based on the ELM, we hypothesized that supporting students as they experienced and explored content in both immersive VR and real-world settings would contribute to greater student engagement (de Freitas & Neumann, 2009).

Due to time constraints and lab sizes we did not conduct formal debriefing with students following VR sessions. However, at the beginning of the sessions, students were provided an orientation of the VR space and a description of what to expect by the instructor. During and following each student's VR experience, the instructor asked general questions about what they were seeing in the VR and linked content to practice. Formal debriefing (for example (Sawyer, Eppich, Brett-Fleegler, Grant, & Cheng, 2016)) would have strengthened the VR sessions and aligned with the *reflection* component of the ELM approach (de Freitas & Neumann, 2009).

Sample

All first-year nursing students (n=205) in the course were eligible to participate. After obtaining university Research Ethics Board approval, a librarian invited students to participate in the project. Email invitations to participate were sent out a month after the last VR session. To mitigate coercion, undue influence, and power imbalance associated with the dual-role of teacher and researcher, the librarian who was not involved with teaching nursing students conducted recruitment. All participants were entered into a draw for two \$20 gift cards.

Data collection

Quantitative data was collected using a modified version of a perceived engagement questionnaire (PEQ) first used to assess experiences with a three-dimensional computer model (Hu, Wilson, Ladak, Haase, & Fung, 2009) and recently used to explore perceived engagement with different immersive environments in an medical anatomy course (Moro et al., 2017). The version we used consisted of five demographic questions followed by ten likert-scale questions asking participants to compare their

engagement across teaching modalities (e.g., VR, labs, lectures, textbooks, etc.) and their general experiences. We modified the questionnaire to reflect the focus of our project (i.e. VR) and the teaching modalities used in our course. Although previously used by others (Hu et al., 2009; Moro et al., 2017), we could not locate psychometric data on this instrument. The Cronbach's Alpha (α) was 0.88 for our sample. A copy of the questionnaire is in the Appendix.

To collect qualitative data, we included text-boxes to several questions asking participants to elaborate on their response to the likert-scale questions and offer additional insight about their experiences. We administered the questionnaire online using Desire2Learn. Because the VR sessions were not mandatory, it is possible that students who opted out of the VR sessions completed the survey. To protect participants, we did not have access to the Desire2Learn site, a staff member not involved with teaching nursing students anonymized the data, and data was not accessed until the final grades were submitted to the Registrar.

Data analysis

Quantitative data was analyzed using descriptive statistics (i.e., percentages). Qualitative data was analyzed using conventional content analysis (Hsieh & Shannon, 2005). Two authors were involved in data analysis. First, one author (DT) followed the method outlined by Hsieh and Shannon (2005) for conventional content analysis and read the data while creating notes on the initial impressions. Next, codes were assigned to the data that were then clustered to create the categories. As per Hsieh and Shannon (2005), codes were defined during data analysis and were derived directly from the data. Codes were then sorted into categories based on how codes were related. Data and categories were then reviewed by a second author (KM) for discussion and verification. Categories were interpreted using concepts from the ELM to explore parallels between the data and ELM concepts.

Results

A total of 46 students (22% of the class) completed the questionnaire. Demographics for the sample are found in Table 1. Most participants were female, 25 years or younger, and recent high school graduates. Previous experience with three-dimensional video games was low but most felt comfortable using a computer.

Table 1: Demographics.

	Demographic value	Frequency	%
Gender	a) Female	42	91
	b) Male	3	7
	c) Prefer not to say	1	2
Age	a) 18–20	32	70
	b) 21–25	10	22
	c) 26–30	3	6
	d) 31–35	1	2
	e) 40+	0	0
Highest education obtain prior to nursing school	a) High school	34	74
	b) College	3	6
	c) University	9	20
Experience with 3D video games	a) Never	24	52
	b) >1 per month	19	42
	c) 1–5 per month	1	2
	d) >6 per month	2	4
Comfortable using a computer	a) Disagree	1	2
	b) Neutral	7	15
	c) Agree	36	78

Perceived Engagement

Figure 2: Students' perceived engagement with the virtual reality (VR) sessions.

Experiences with Virtual Reality

Figure 3: Students' experiences with the VR sessions.

Quantitative findings

Students reported feeling more engaged when using VR than with other learning activities (Figure 2). Specifically, students stated engagement during VR sessions was higher than during both active (i.e., labs) and

passive (i.e., textbooks) learning techniques. Students also reported positive experience with how VR was integrated into the course. For example, they found the VR sessions helped consolidate their knowledge by facilitating their ability to apply anatomy and physiology concepts to health assessment (Figure 3). Furthermore, students found VR easy to use and would like to see more VR activities integrated within the course. Lastly, many students also reported a desire to access VR equipment outside of scheduled class activities to support their learning related to anatomy and physiology. While our sample size was small ($n=46$) and may not be representative of the larger population of nursing students, it should be noted that after two reminder emails, our response rate was 22% which is approaching the expected response rate of 25% for web-based questionnaires with two reminders (Mol, 2017).

Qualitative findings

The qualitative data supported the quantitative data with most students reporting favorable experiences with VR. Students responded to all eight of the free text box questions. Response rates varied from 42 responses (What did you like most about the VR sessions?) to 13 (It is easier for me to learn anatomy and physiology when I can visualize material) with the average being 22 responses. We identified themes related to supported *control*, *complementary contexts*, and *visualization*.

Supported control

Responses suggested students appreciated the control the VR equipment provided them and compared this control to several other ways of learning. The theme of supported *control* contains elements that align with the ELM components of *reflection* and *forming*. VR provided students with opportunities to focus on material or concepts that required more attention in a supportive environment. For example, students commented “The VR is more fun than a lecture because you’re in control and it’s interactive”, “the VR gave students more control over what we wanted to see rather than what the videos showed us”, and “although textbooks have pictures and diagrams ... the VR provided students the ability to visualize whatever we wished to see”. The ability to control exploration was also reported generally as opposed to comparisons: “It literally put you inside whatever organ you wanted and you could see the processes working”, and “(I liked) how hands on and self-directed it was as well as how much you could explore”. Control was important to students, but they also highlighted the importance of the instructor support: “they felt like guided tours and were very helpful in solidifying my understanding of important processes of the body”, and “it helped to go through it with the instructor because it was a different way that they could explain concepts”. Collegial support was also reported: “you need a partner with you in order to know you are safe, so it is not something an individual can do independently”. The need for a partner during the VR sessions likely pertains to the partner’s ability to physically redirect the user because the VR headset impedes one’s ability to interact with the immediate environment, thus, there is a risk of tripping over furniture or bumping into walls. During the sessions the instructor took on this role, however, if students were to access the equipment on their own time (something we promoted), it would be safer if they did so with a partner.

Complementary contexts

Several students reported the VR sessions were complementary to learning that occurred in the labs and lectures. The theme of *complementary contexts* mirrors the ELM element of *testing* in different situations. For example: “I felt that the labs and VR were useful, go hand in hand with each other and I thought the VR sessions enhanced our learning in labs” and “I found the VR combined the anatomy and physiology we were learning in class in a very tangible way”. Further, one student commented on how they were able to “apply what we were learning in the VR ... to understand more of the concepts”. Another student echoed this sentiment: “seeing these (organs) up front and trying to understand what is shown makes me think and apply the concepts we are

learning in anatomy and physiology (lecture)". Such comments suggest students found the VR offered a complementary learning opportunity where they could explore concepts taught in lab and lecture. The complementary nature of the VR was also mentioned in relation to more self-directed activities such as textbook reading: "reading the textbook is good to get a basis of what anatomy is but seeing it in front of you and being able to explore this enhances my learning".

Visualization

The ability to visualize anatomy was repeatedly praised by students. The theme of *visualization* parallels the ELM concept of exploration. One student commented: "it is one thing to explain the concept, but it is much easier to understand once you are able to see and visualize the concept". Similarly, another student commented: "we were able to look through body parts in a way we couldn't imagine". Another student commented on the benefit of visualization on patient care: "it's nice to see what is happening while I am assessing a patient". The benefit of visualization was compared to diagrams in the textbook: "as a visual learner it was a lot more helpful to have the VR sessions to learn and understand the functions of the body compared to the textbook which only provided 2D images compared to the 3D images in the VR lab". Another student echoed the three dimensional benefit: "it was interesting to see a 3D model of the heart". Comparisons were also made to videos: "the videos are not interactive whereas the VR was". While most comments were positive, not all students found the VR helpful: "It gave us a visual of how things work but I didn't feel like I learned anything more than I would have in lab".

Discussion

The quantitative findings suggest students perceived their engagement to be higher in the VR sessions than other learning techniques and the overall experience was positive. Our findings are similar to what others have reported (Jensen et al., 2018). However, like others, we did not evaluate learning or achievement; thus, we do not claim the VR sessions were superior teaching strategies. However, student engagement is a precursor to learning (Foronda et al., 2020) and an important element to consider when using VR for teaching (Davies et al., 2018). That being said, we align ourselves with Jensen and colleagues' in suggesting future research should explore the relationship between technologies such as VR and learning achievements (Jensen et al., 2018). Likewise, we echo others in suggesting that supporting nursing students to learn bioscience content effectively requires a multifactorial approach involving both curricular and course level attention (Jensen et al., 2018; McVicar et al., 2015).

The qualitative findings lend support to ELM (de Freitas & Neumann, 2009) as a useful model to conceptualize how VR may contribute to learning. As we have shown, VR supported students to control what they experienced and explored. According to de Freitas and Newman, empowering students to control what they explore "aids the learner to find new boundaries, to push back on what they know or to help them to engage socially and conceptually with others (p. 346). Overwhelmingly students reported how they appreciated the ability to explore, look around, and "see how the body operates". VR is a tool that can personalize their experience.

Furthermore, ELM conceptualizes virtual and real world experiences as being integrated and reinforcing in terms of learning (de Freitas & Neumann, 2009). Students who participated in our VR sessions commented on how they were able to apply concepts across VR sessions, lectures, and labs. They saw these environments not as separate entities but rather as complementary opportunities to explore concepts. The complementary nature of virtual and real world environments was evident when students wrote about how they appreciated the visual aspects of the VR when they were reading their texts, listening to lectures, or practicing in labs. According to ELM, when students consider concepts from VR while experiencing settings in the real-world (i.e., lectures, labs), they are participating in reflection which can assist with the formation of abstract concepts and, ultimately, testing of those concepts in different contexts (de Freitas & Neumann, 2009).

Strengths and limitations

Limitations of this small-scale project reflect the early integration of VR into our course. The project was limited in scale and was not an experimental design. We did not measure objective learning outcomes. We used a questionnaire with no psychometric properties reported in the literature. In addition, we expect that our use of an online format to collect qualitative data may have limited the depth of responses from students. Finally, our sample size was low with only 46 participants; however, we sent two reminder emails and our response rate was 22% which is expected for online questionnaires with two reminders (Mol, 2017). Nonetheless, the small sample size limits generalizability of our findings.

Our findings provide a first step in evaluating the potential for VR within a bioscience course in nursing. In addition, our use of a theoretical framework to support the integration of VR into the course, and to frame our project design offers a clear perspective for readers to understand the project and hypothesize about the potential for VR use. Future studies can build upon our results by using experimental designs and focusing on learning outcomes that may be relevant for the use of VR in bioscience nursing courses’.

Conclusions

Integration of VR sessions into an anatomy, physiology, and health assessment course for nursing students resulted in students feeling more engaged than during other learning activities. Students sought more time using VR equipment both within and outside the classroom. VR provided students control over their learning. They were able to integrate real and virtual environments and appreciated the visualization aspects. The ELM is a useful way of conceptualizing how virtual and real environments may contribute to learning. Future research investigating VR and learning outcomes will be helpful to develop the field.

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Informed consent: Informed consent was obtained from all individuals included in this study.

Ethical approval: The local Institutional Review Board deemed the study exempt from review.

Appendix

Perceived Engagement with Virtual Reality Questionnaire

1. What best describes your gender?

- a) Female
- b) Male
- c) Prefer to self-describe <free text box>
- d) Prefer not to say

2. What is your age?

- a) 18–20
- b) 21–25
- c) 26–30
- d) 31–35
- e) 36–40
- f) 40+

3. Before nursing school, what is the highest level of education?

- a) High School
- b) CEGEP
- c) College Diploma
- d) University Undergraduate
- e) University Graduate (Masters, PhD)

4. The optimal time to spend in the Virtual Reality lab for this course is:

- a) No time
- b) 1 time
- c) 2 times
- d) More than 2 times

Please answer the following questions by assigning a rating based on the following scale:

- a) Strongly agree
- b) Somewhat agree
- c) Neutral
- d) Somewhat disagree
- e) Strongly disagree

5. I was more engaged in the virtual reality sessions than I was in the labs.

Please explain (optional): <free text box>

6. I was more engaged in the virtual reality sessions than I was in the lectures.

Please explain (optional): <free text box>

7. I was more engaged in the virtual reality sessions than I was while reading the textbook.

Please explain (optional): <free text box>

8. I was more engaged in the virtual reality sessions than I was while watching the videos.

Please explain (optional): <free text box>

9. The virtual reality sessions helped me apply anatomy and physiology to health assessment more so than other learning strategies.

Please explain (optional): <free text box>

10. It is easier for me to learn anatomy and physiology when I can visualize material using virtual reality.

Please explain (optional): <free text box>

11. The virtual reality equipment was easy to use.

12. I would prefer if more labs were supplemented with virtual reality.

13. I prefer learning on the computer compared to hard copy.

14. I feel comfortable using a computer.

15. I would access the virtual reality lab on my own to learn anatomy and physiology.

16. What did you like best about the virtual reality experience?

<free text box>

17. What did you not enjoy about the virtual reality experience?

<free text box>

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