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Title: Learning to Manage COVID-19-induced Respiratory Distress in the Immersive Virtual Reality Simulation: A Pre-Experimental Study

Titre : Apprendre à maîtriser la détresse respiratoire causée par la COVID-19 grâce à une simulation en réalité virtuelle immersive : une étude pré-expérimentale

Halyna Yurkiv[1] https://orcid.org/0000-0003-2193-2977

[1] Arthur Labatt Family School of Nursing, Western University, Ontario, Canada hyurkiv@uwo.ca

Voir la page suivante pour les coauteur·trices

See the next page for coauthors

Cristina Catallo[2] https://orcid.org/0000-0003-4607-7380 Kristine Newman[2] https://orcid.org/0000-0003-0633-4725

[2] Daphne Cockwell School of Nursing, Toronto Metropolitan University, Ontario, Canada

Abstract

Introduction: Undergraduate nursing students have limited theoretical knowledge of and practical learning opportunities to manage COVID-19 respiratory distress. Immersive virtual reality simulations in nursing represent a new area of educational interest that has been understudied in Canada.

Objective: This study aimed to measure the potential impact of immersive virtual reality simulation on content knowledge in respiratory distress induced by COVID-19, as well as perceived learning and perceived confidence in managing this condition among third- and fourth-year undergraduate nursing students.

Methods: A pre-experimental design with a one-group pretest-post-test was employed. Nursing students (n = 30) were recruited through convenience sampling to participate in a single immersive virtual reality simulation session. Data were collected using the Respiratory Distress Management Knowledge Test, the Simulation Effectiveness Tool-Modified (subscales: Learning and Confidence), and an open-ended question.

Results: The results showed an increase in knowledge (p=0.01). Participants reported a high perception of learning and confidence, and shared that this simulation helped them identify areas for improvement and strengthened their existing skills.

Discussion and Conclusion: These results suggest that this immersive virtual reality simulation has the potential to enhance students' knowledge about respiratory distress. Subjective evaluations highlight its educational potential. Further studies could explore simulation's impact on nursing students and professionals by integrating a control group and other validated measures.

Keywords: immersive virtual reality simulation, deteriorating condition, respiratory distress, undergraduate nursing students

Résumé

Introduction : Les étudiants de premier cycle en soins infirmiers ont un accès limité aux connaissances théoriques et aux opportunités pratiques pour gérer la détresse respiratoire liée à la COVID-19. Les simulations en réalité virtuelle immersive (SRVI) en soins infirmiers représentent un nouveau domaine d'intérêt éducatif encore peu étudié au Canada.

Objectif : Cette étude visait à mesurer l'impact potentiel de la SRVI sur les connaissances concernant la détresse respiratoire causée par la COVID-19, ainsi que sur l'apprentissage et la confiance perçus dans la gestion de cette condition chez les étudiants de troisième et quatrième années de premier cycle universitaire.

Méthodes : Un devis pré-expérimental avec pré et post-test a été utilisé. Trente étudiants ont été recrutés par échantillonnage de convenance pour participer à une session de SRVI. Les données ont été collectées via le *Respiratory Distress Management Knowledge Test*, le *Simulation Effectiveness Tool-Modified* (sous-échelles : Apprentissage et Confiance), et une question ouverte.

Résultats : Les résultats ont montré une augmentation des connaissances ($p=0.01$). Les participants ont rapporté une perception élevée d'apprentissage et de confiance, et ont indiqué que cette simulation les avait aidés à identifier les domaines à améliorer et avait renforcé leurs compétences existantes.

Discussion et conclusion : Ces résultats suggèrent que la SRVI a un potentiel de renforcer les connaissances des étudiants sur la détresse respiratoire. Les évaluations subjectives soulignent son potentiel pédagogique. De futures études pourraient explorer son impact auprès des étudiants et des professionnels en soins infirmiers, en intégrant un groupe témoin, et d'autres mesures validées.

Mots-clés : simulation en réalité virtuelle immersive, condition détériorée, détresse respiratoire, étudiants de premier cycle en soins infirmiers

INTRODUCTION

The COVID-19 pandemic has highlighted significant gaps in the provision of experiential learning and clinical practicum opportunities in undergraduate nursing education (Head et al., 2022). Nursing programs had to adapt their clinical placement programs, often shifting to online or hybrid models (Head et al.). The global demand for healthcare providers has spiked during the COVID-19 pandemic and continues to grow post-pandemic (Wilensky, 2022) while institutions are challenged to keep up with the demand for a highly trained workforce, including nurses (Brown et al., 2023). This challenge to provide hands-on learning experiences essential for nursing students prompts educators to seek alternative methods to deliver experiential learning.

There has been a growth in the use of immersive virtual reality (IVR) in healthcare education (Salcedo et al., 2022) to provide complementary opportunities to enhance or augment initial skill acquisition, skill retention, and slow skill decay among the next generation of healthcare providers (Linde & Miller, 2019). IVR, a subtype of virtual reality technology, offers a highly immersive educational experience that engages learners emotionally (sparks curiosity and enjoyment) and cognitively (arouses learner's focus and motivates to continue staying invested in the process), thereby actively involving learners in the learning process (Dubovi, 2022; Jeong & Lee, 2019). Essential components of IVR modality include a head-mounted device with hand controllers that immerse a user into an artificially created, three-dimensional environment (Jeong & Lee). Literature suggests that IVR simulations are particularly effective in improving procedural skills and clinical judgment in complex situations, wherein learners need to identify critical cues in a timely manner, prioritize their interventions, and escalate care (Adhikari et al., 2021; Chang & Lai, 2021; Zackoff et al., 2020). Effective response to deteriorating conditions is a core competency for Registered Nurses (College of Nurses of Ontario [CNO], 2018). Under ideal circumstances, nursing students ought to be exposed to experiential learning related to recognizing and managing deteriorating conditions in their clinical placements. Historically, recognizing and acting upon deteriorating conditions (i.e., respiratory distress) has relied on teaching during direct patient care (Raab et al., 2024). However, exposing nursing student learners to patients in clinically deteriorating conditions in real life clinical settings is an opportunistic experience that may be difficult to attain for all students (Adhikari et al.). As a result, students demonstrate challenges with identifying respiratory distress and subsequent (impending) respiratory failure and with

appropriately escalating care (Odum et al., 2023). The immersive virtual reality simulation may provide access for more students to be exposed to such a learning opportunity to accelerate recognition of respiratory distress among a greater number of nursing students (Raab et al.).

While COVID-19 cases have significantly decreased, the need for robust training in managing respiratory distress remains pertinent. Respiratory distress, characterized by an abnormal respiratory rate (tachypnea) and increased respiratory effort, can result from various widespread conditions, including infections, chronic illnesses, and acute respiratory events. Respiratory symptoms that require timely interventions also frequently occur in patients with COVID-19 (Leonardsen et al., 2020). The recent pandemic has shown the need for nurses' competence in observation, assessments, and intervention when caring for patients with respiratory insufficiency. For instance, the pre-pandemic cohort of the new graduate nurses reported ill preparedness and low confidence in their clinical judgment abilities related to managing respiratory distress (Herron, 2018), which was validated by the similar experiences of the 2020 cohort of the new graduate nurses (McMillan et al., 2023). In addition, patients may be unable to communicate their needs or report their symptoms verbally and these symptoms may be overlooked by those nurses who were not exposed to learning management of respiratory distress in their clinical placement, delaying interventions and leading to severe consequences, like acute respiratory distress syndrome and death (Leonardsen et al.).

It may be challenging to ensure exposure to respiratory distress management in clinical settings for all nursing students. A limited experience due to insufficient experiential learning opportunities, especially during senior years of nursing school, necessitates nursing educators to explore and adopt new avenues that would allow third- and fourth-year nursing students to overcome barriers to accessing such educational opportunities in a safer way for both a patient and a nursing student. Literature suggests that IVR simulations lead to increases in knowledge related to recognizing and managing impending respiratory distress among new graduate nurses (Zackoff et al., 2020), knowledge of airway management among nursing students (Samosorn et al., 2020), and knowledge related to demonstrating correct procedures in emergencies among medical students (Bucher et al., 2019). In addition, new graduate nurses participating in the IVR simulation in recognition of respiratory distress were significantly more likely to correctly recognize respiratory distress than their counterparts only receiving conventional onboarding training (Raab et al., 2024). At the same time, IVR modality may or may not enhance learning when compared to

other simulation modalities (i.e., desktop-based VR simulation) (Lavoie et al., 2024) due to increased cognitive load created by a perception of being immersed in the artificially created IVR simulation environment (Makransky et al., 2019). In addition, although IVR emerges as a promising tool for simulation-based education, research on IVR simulation's impact on nursing students in managing deteriorating conditions is nascent (Adhikari et al., 2021; Chang & Lai, 2021; Farra et al., 2018). More research is needed to establish IVR simulations' merit in helping nursing students develop clinical judgment skills in recognizing and managing deteriorating conditions (i.e., respiratory distress). The IVR modality was explored in this pre-experimental study as a potential substitute option for a real-life clinical experience for those unable to witness or participate in recognition and management of this deteriorating condition in the clinical setting. This study was guided by the following research questions:

1. "Does IVR simulation increase knowledge in COVID-19-induced respiratory distress management in undergraduate third- and fourth-year nursing students?"
2. "Does IVR simulation contribute to the perceived learning of COVID-19-induced respiratory distress management in undergraduate third- and fourth-year nursing students?"
3. "Does IVR simulation contribute to the perceived confidence in COVID-19-induced respiratory distress management in undergraduate third- and fourth-year nursing students?"

OBJECTIVE

Based on the variability in research findings related to the use of IVR simulation for experiential learning, the objective of this study was to measure the potential impact of immersive virtual reality simulation on content knowledge in respiratory distress induced by COVID-19, as well as perceived learning and perceived confidence in managing this condition among third- and fourth-year undergraduate nursing students.

Theoretical Framework

Kolb's Experiential Learning Theory (1984) model guided this research study. The main premise of this theory is that learning is a continuous process that is best developed through experiences (Kolb). For Kolb, the concepts of learning, knowledge, and experience are intertwined. This can be seen in Kolb's definition of learning as "the process whereby knowledge is created

through the transformation of experience" (Kolb, p. 41). In addition, learning is an active, continuous, and cyclical process that involves progression through the four modes (Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation) and those who were able to progress through these modes of learning will attain it (Kolb).

The design features of IVR simulations should align with each of the four modes of the Experiential Learning Theory Model to ensure that this experiential learning opportunity allows learners to go through a comprehensive learning cycle (Fromm et al., 2021). The 1) Concrete Experience mode aligns with design features like realistic surroundings (i.e., high-quality graphics, realistic avatars) and interaction with virtual agents to ensure that a learner can experience what it feels like to be in a particular situation with plausible and not plausible outcomes (Fromm et al.). These design features were reflected in this study's IVR simulation when participants were exposed to a virtual patient in the IVR simulation, and asked to perform an initial virtual patient assessment, to stabilize their virtual patient's respiratory distress condition, and to reassess their interventions.

The 2) Reflective Observation mode aligns with design features like a realistic scenario, instructor's feedback, different scenario endings based on performance, and interaction with virtual agents (Fromm et al., 2021). Going through the Reflective Observation mode ensures that a learner can observe the reactions of the virtual agent to the learner's interventions and reflect upon their emotional response to the scenario during debriefing (Kolb, 1984). Learners shared their reflections during the debriefing phase of the simulation, during which they shared their experiences with this IVR simulation and emotions it evoked. The facilitator engaged nursing students in guided discussions, allowing them to explore their feelings and thoughts about identifying and taking care of a virtual patient in respiratory distress. The reflection was structured around the design features, such as realistic scenarios and dynamic responses of the virtual patient to nursing students' interventions (i.e., raising the head of the bed to promote oxygenation, administering oxygen, administering medications to relieve crackles in the lungs, or not intervening). Nursing students reflected on what happens to the virtual patient in respiratory distress when they intervene versus do not intervene, and on their actions and emotions when not knowing how to intervene. During the debriefing stage, participants also received feedback from the facilitator on what went well and what could be improved. Such an opportunity for reflection contributed to students' understanding of the clinical decision making to stabilize a patient in respiratory distress and fostered their emotional awareness in a high-stakes clinical situation that can be carried into their future practice.

The 3) Abstract Conceptualization mode presented learners with an opportunity to draw from their knowledge from clinical foundations learned about respiratory distress in nursing courses (i.e., pathophysiology, health assessment) and integrate this knowledge and ability to analyze presenting cues into this simulation scenario (Kolb, 1984). Nursing students' analysis of the situation and connection to the pathophysiological concepts helped them understand the underlying principles of respiratory distress induced by COVID-19 and informed their actions during the simulation. For instance, later in the debriefing phase, participants shared that they linked their understanding of the hypoxia to their virtual patient's increased rate of breathing, agitation, and increased heart rate.

Finally, 4) Active Experimentation mode allows learners to apply and test their newly acquired or modified knowledge and skills in subsequent experiential opportunities (Kolb, 1984). This IVR simulation had embedded features designed to equip participants with the ability to recognize respiratory distress and manage it in future simulation sessions or real-world situations. For example, nursing students interacted with virtual medical equipment (i.e., stethoscope, vital sign monitor, oxygenation equipment, and medications) and experimented with different interventions to observe the effects of their interventions in a safe and controlled learning environment. Such hands-on engagement allowed nursing students to test the effectiveness of their interventions to reinforce clinical strategies that they can implement in real-life situations or other simulations and solidify understanding of the pathophysiological processes that inform clinical decision-making. For instance, performing lung auscultation allowed nursing students to hear crackles in the virtual patient's lungs, which can prompt nursing students to assess this indicator of respiratory distress in subsequent contexts. Conversely, those participants who missed this assessment cue witnessed a deterioration of their virtual patient. Through this simulation nursing students recognized the immediate consequences of their interventions, which can prepare them to transfer these skills and mobilize knowledge in new contexts, where prompt clinical decision making is critical to the patient's health outcome.

It was hypothesized that the IVR simulation of COVID-19 induced respiratory distress management with embedded strategies that mobilize Concrete Experience, Reflective Observation, and Abstract Conceptualization modes would influence third- and fourth-year nursing students' perceived learning and perceived confidence scores as well as increase knowledge scores related to managing a virtual patient avatar in respiratory distress induced by COVID-19.

METHODS

Design

This study employed a one-group pretest-post-test pre-experimental design (Sidani & Braden, 2021). Pre-experimental designs are well suited for studies conducted in naturalistic settings, such as educational environments, where random assignment or strict control over conditions may not be feasible or ethical (Sidani & Braden). Our study aimed to evaluate the intervention's effectiveness in a real-world context with authentic participant experiences at a single site. Pre-experimental designs are indicated for initial exploration of the interventions before conducting larger-scale studies (Sidani & Braden).

Intervention

Simulator Type

This intervention comprised a combination of hardware and IVR software. The hardware technology included Oculus Quest head-mounted device with hand controllers connected to a laptop via Bluetooth wireless connection. The software was developed by the local Canadian company Lumeto and pre-downloaded into the head-mounted device and a laptop by the first author, according to the Lumeto's instruction package. This study reports on findings related to the beta-testing stage of the software.

Participant Orientation

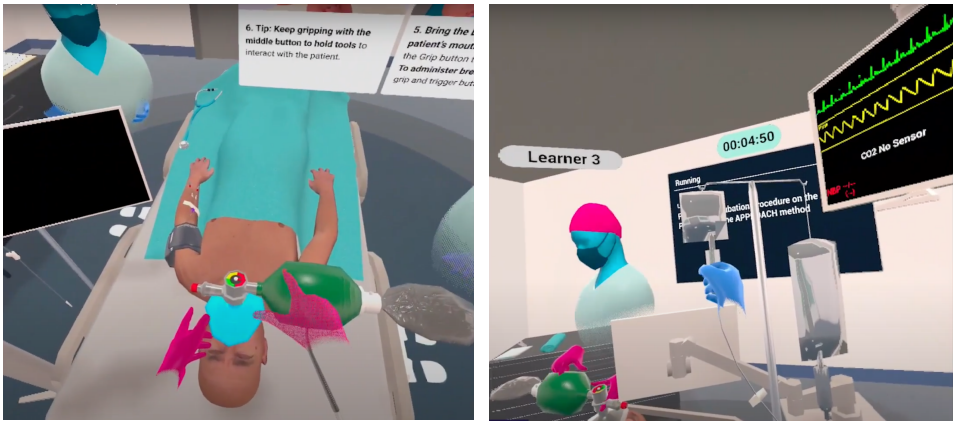
The orientation to the equipment and to the immersive virtual environment lasted approximately 15 minutes. Participants were first oriented to the simulation hardware. This included showing the participants how to adjust head stripes and lens width on the head-mounted device. Participants were also introduced to the toggles and controls located on the Oculus Quest hand controllers. Participants then put their head-mounted device on, and each device was calibrated based on the Oculus Quest built-in instructions according to a participant's height and dominant hand. The image transmitted into the head-mounted device was synchronized with a laptop used by the facilitator to launch the simulation. Following this process, the IVR software used for this study that immerses a user into the artificially created environment was launched. The Lumeto's built-in training module instructed participants how to operate controls (i.e., grab equipment, teleport, interact with equipment).

Simulation Environment

The simulation was administered at a large student lounge at a Canadian University where participants were enrolled. Simulations were scheduled between 9 a.m. and 5 p.m. to ensure that diurnal variations did not affect participants' responses in the surveys. The lounge was cleared of chairs and tables to omit environmental obstacles for the participants wearing the IVR head-mounted devices. Only participants and the simulation facilitator were present in the lounge during the simulation. The immersive virtual environment was an acute clinical environment resembling an acute medicine unit where a virtual patient avatar was admitted. Within this virtual environment, participants had access to equipment like patient's chart, vital signs machine, a stethoscope, personal protective equipment (PPE), medication cart, oral suctioning equipment, oxygenation equipment, and intravenous (IV) therapy equipment (Figure 1 displays snapshots of the IVR environment).

Figure 1

Participant point of view during IVR simulation



Simulation Scenario

For the Concrete Experience mode of learning, the IVR simulation scenario involved a 56-year-old male with a history of chronic obstructive pulmonary disease and diagnosed with COVID-19, who was admitted to the acute medicine ward for shortness of breath and worsening cough. Students were told they would conduct a focused respiratory assessment and obtain vital signs,

determine the patient's health status (clinically stable versus unstable), and intervene accordingly as they progress through the scenario.

This IVR simulation included three modules. Each of the three IVR simulation modules lasted for about 10 minutes. The educational intervention was administered once after the orientation. Upon receiving the Transfer of Accountability report from the facilitator and reading the patient's health records, the facilitator prompted participants to assess their virtual patient, for which they must have worn appropriate PPE.

In module 1, the learning objective was to practice the correct donning and doffing of PPE when caring for a patient with a confirmed case of COVID-19. Participants were asked to verbalize which PPE should be worn, how does the COVID-19 virus spread, and what is the correct sequence of Donning and Doffing PPE. Participants responded to these questions and then practiced Donning and Doffing PPE in the IVR environment.

The facilitator then guided participants to begin module 2 with a learning objective to apply theoretical, conceptual, and practical knowledge relevant to taking care of a clinically stable patient with COVID-19. The setting within the virtual environment in this module was the following: the patient is in isolation in their private room, sitting upright in bed, awake. Participants were asked to demonstrate CNO competencies by introducing themselves to the patient, confirming the correct identity of the patient, and performing the health assessment of this patient (CNO, 2018). The facilitator asked participants to think aloud about what assessment needed to be done (i.e., check vital signs, perform a focused respiratory assessment). Participants were also asked to note and verbalize whether their assessment findings were within normal or abnormal ranges.

The facilitator then asked participants to begin module 3, wherein the learning objective was to apply theoretical, conceptual, and practical knowledge relevant to the management and stabilization of the COVID-19 induced respiratory distress event. In this module, participants were told that the virtual patient they have previously assessed (in module 2) began to experience worsening symptoms. As a result, participants had to perform appropriate nursing interventions to stabilize the patient experiencing respiratory distress. The options for nursing interventions embedded in this software module included suctioning of oral secretions, adjusting the height of the bed and angle of the head of the bed, taking vital signs, auscultating lung sounds, administering oxygen therapy, and escalating the incident by calling the Nurse Practitioner (NP) on call for further recommendations. Participants were asked to call NP on call to recommend and obtain an order for

a medication that would relieve crackles. Participants were also asked to critically think about a safe route of medication administration based on the virtual patient's health condition.

Debriefing

Debriefing facilitated Reflective Observation and solidified Abstract Conceptualisation. Debriefing occurred after the post-intervention data collection, lasted approximately 15 minutes, and was led by the first author. The facilitator was a Registered Nurse with expertise in the acute clinical care. Debriefing was guided by the RUST model (Reaction, Understanding, Summary, and Take-home messages) (Şahin & Başak, 2021). In the Reaction phase, participants were asked about their views regarding the IVR simulation scenario and their actions. In the Understanding phase, participants were asked to reflect on and share their thinking processes about their actions linking them to pathophysiological and clinical concepts. This helped nursing students solidify their understanding of the underlying principles that informed their interventions during the IVR simulation. In the Summary phase, participants were encouraged to share what they learned through this scenario. In the Take-home message phase, participants examined and verbalized their areas of strengths and areas for improvements that they can transfer into the clinical setting in case they have to care for a similar patient in real life.

Sample

Sample Size Calculation

The sample size for this one group pre-post-test pre-experimental study was calculated using G*Power software – a software commonly employed for power analysis in research for a wide variety of statistical tests (Kang, 2021). To calculate the sample size, the following input parameters were entered: 1) a one-tail t-test was selected based on the directional hypothesis that an intervention will increase scores in knowledge; 2) a moderate effect size was hypothesized, corresponding to Cohen's d = 0.5, a widely accepted estimate in health-related research (Kumar et al., 2022); 3) significance level was set at 0.05 to ensure a 5 percent chance of Type I error, and 4) the desired power was set at 0.8 to achieve an 80 percent chance of detecting statistically significant differences between samples. As the intervention was administered only once, a t-test family matched pairs statistical test was selected. Therefore, the suggested sample size in G*Power was 27 participants.

A total of 30 fourth (n = 14) and third (n = 16) year undergraduate nursing students attending a Bachelor of Science in Nursing (BScN) program expressed interest and were recruited using a

convenience sampling method. Participants were recruited via email, social media, and in-person communication after obtaining approval from the Research Ethics Board at the university where the study was conducted. Prospective participants were provided with a consent document detailing the potential benefits and risks of IVR simulation exposure. They were given the opportunity to ask questions before providing their consent. The researcher reviewed the study information with participants and obtained their written consent before administering the intervention.

Inclusion and Exclusion Criteria

Nursing students were selected to participate in this study if they self-reported: 1) being in their third or fourth year of the BScN program; 2) not having previous experience in managing respiratory distress; 3) not having binocular vision abnormalities, a history of severe motion sickness, epilepsy disorder, earache, migraine, heart conditions, or psychiatric disorders (the manufacturer of the head-mounted device does not specify which psychiatric conditions would exclude the use of the head-mounted device. However, we assume that anxiety, schizophrenia, or psychosis, for example, would prevent the use of the device due to potentially highly realistic anxiety-provoking content), and 4) not being pregnant. The rationale for including undergraduate third- and fourth-year nursing students in this study was based on their successful completion of the key courses relevant to this simulation (i.e., health assessment, pathophysiology, pharmacology, nursing practice). Hence, although nursing students in this study have not managed an episode of COVID-19-induced respiratory distress, the assumption was that previous knowledge obtained in milestone courses would provide an appropriate level of theoretical knowledge base to recognize and act on critical cues in the IVR simulation scenario which, on the other hand, might not be a realistic expectation for first- and second-year nursing students in a four-year program.

Data Collection and Instruments

An electronic survey method was used to collect participant data. Participants were asked to come up with a personal study number to de-identify their responses. Demographic information was gathered immediately before the intervention. A multiple-choice, NCLEX-style Respiratory Distress Management Knowledge Test (RDMKT) was developed by the first author based on a review of available literature on COVID-19 respiratory distress with key topics including pathophysiology, clinical signs and symptoms, management strategies, and personal protective equipment guidelines. The multiple-choice questions were generated to reflect these key topics and reviewed by the research team with experience in nursing education and clinical practice to ensure

their relevance, clarity, and accuracy. The RDMKT was administered immediately before and after the intervention. The Cronbach's alpha value for the pre-test was $\alpha = 0.2$, indicating poor internal consistency within the ensemble of items. That could be attributed to the fact of measuring different attributes of the knowledge about respiratory distress management. However, questions were maintained and considered separately, as they allow for the measurement of different aspects of the targeted knowledge.

The Simulation Effectiveness Tool-Modified (SET-M) instrument consisting of 19-item was used to collect post-simulation data. Developed by nursing faculty from seven schools, SET-M has four subscales: Prebriefing, Learning, Confidence, and Debriefing (Leighton et al., 2015). The SET-M tool uses a 0-2 scale for each item, with a maximum possible score of 12 for each subscale. Based on the study objectives, we focus on reporting data analysis findings related to the Learning and Confidence subscales. The SET-M instrument has demonstrated good validity and reliability for these subscales (Learning $\alpha = .85$; Confidence $\alpha = .91$) in the original psychometric evaluation study (Leighton et al.) and acceptable reliability in this study (Learning $\alpha = .75$; Confidence $\alpha = .75$). In 2020, the SET-M (Leighton et al.) was modified to include a virtual debriefing element. However, we did not use this version of SET-M since debriefing in our study took place in person.

Data Analysis

Descriptive statistical tests were used to analyze the socio-demographic characteristics of the sample in this study. Descriptive statistic measures of central tendency (mean, median), range, and variability (SD) were also used to analyze the total scores for the RDMKT at the pretest and post-test, and SET-M at the post-test. A paired sample t-test was carried out to answer the first research question. RDMKT data were assessed for normal distribution. The distribution of the scores obtained from the RDMKT was examined for normality by assessing the skewness values using the Shapiro-Wilk test. The skewness value for the RDMKT data on the pre-test was -.012, and for the RDMKT on the post-test was .026, demonstrating a fairly symmetrical distribution. The mean scores, frequency, and percentages pertinent to Learning and Confidence subscales in the SET-M scale were examined to address the second and third research questions. In addition to the survey results, students were given the opportunity to respond to an open-ended question asking for their feedback about the IVR simulation experience. Their narrative responses were analyzed using content analysis method (Erlingsson & Brysiewicz, 2017).

ETHICAL CONSIDERATIONS

The study received ethical approval REB 20022-031 from the research ethics board of Toronto Metropolitan University.

RESULTS

Demographic Characteristics

Participants ranged in age from 19 to 25 years old (M = 21; SD = 1.56). Twenty-eight participants (93.33%) identified as women and two (6.67%) identified as men. Participants' cumulative grade point average (CGPA) was between 2.67 and 4.27 (M = 3.68; SD = .39) among 30 participants. Sixteen participants (53.33%) were enrolled in the third year and fourteen participants (46.67%) were enrolled in the fourth year of the four-year BScN nursing program. Twenty (66.70%) participants had recent work experience as a personal support worker or a clinical extern.

Respiratory Distress Management Knowledge

Research question 1 - "Does IVR simulation increase knowledge of COVID-19-induced respiratory distress management in undergraduate third- and fourth-year nursing students?".

Respiratory distress management knowledge was assessed using the RDMKT instrument during the pre-test and post-test. The RDMKT evaluated content knowledge of COVID-19 induced respiratory distress and its management, including appropriate personal protective equipment required to wear when in contact with COVID-19-positive patients, knowledge of the initial nursing actions related to respiratory distress management, symptoms and specific assessment findings present during respiratory distress induced by COVID-19, and conditions that can predispose someone to experience respiratory distress. A paired sample t-test suggested a statistically significant change in respiratory distress knowledge from the pre-test to the post-test (t-test (t(df = 30) = -3.56, p = 0.01). In addition, the effect size was computed to indicate the practical significance of the change in this outcome post-intervention. The effect size (Cohen's d coefficient = -0.65) indicated a moderate change in the level of respiratory distress management knowledge following the intervention.

Research question 2 - “Does Immersive Virtual Reality (IVR) simulation contribute to the perceived learning of respiratory distress management in the undergraduate third- and fourth-year nursing students?”

Perceived learning of managing COVID-19-induced respiratory distress was assessed using the Learning subscale of the SET-M instrument at the post-test. The Learning subscale measured the extent to which IVR simulation transformed participants’ perception of feeling prepared to recognize and respond to the changes in the patient’s condition. A total of 30 BScN students completed the SET-M survey. Most participants strongly agreed that this IVR simulation was effective for their learning. In this study, participants’ scores on the SET-M Learning subscale ranged from 5 to 12. The mean score was 10.6 (*SD* = 1.79), with a median of 11. In this context, scores above 9 out of 12 are considered relatively high, reflecting participants’ strong agreement with statements about the perceived learning construct. Descriptive Statistics of the SET-M Learning subscale are displayed in Table 1. Frequencies and percentages related to Learning subscale items are displayed in Table 2.

Research question 3 - “Does Immersive Virtual Reality simulation contribute to the perceived confidence in managing patients in respiratory distress in the undergraduate third- and fourth-year nursing students?”

Perceived confidence was assessed using the Confidence subscale of the SET-M instrument at the post-test. The Confidence subscale measured participants’ perceived capability to implement effective care and interventions. A total of 30 BScN students completed the SET-M survey. Most participants strongly agreed that this IVR simulation was effective for their confidence building. Results of descriptive statistical tests showed high mean scores for the outcomes of interest confidence (M = 9.93/12, SD = 2.56). Descriptive Statistics of the SET-M Confidence subscale are displayed in Table 1. Frequencies and percentages related to Confidence subscale items are displayed in Table 2.

Open-Ended Response Analysis

In addition to the survey results, students were given the opportunity to respond to an open-ended question asking for their feedback about the IVR simulation experience. Of the 30 participants, 29 provided narrative responses, with some of them being specific to respiratory distress content knowledge, learning, and confidence development. Some participants (n = 6) reported that this IVR simulation increased their confidence and preparedness in clinical skills and

decision-making. Others (n = 3) shared that this IVR simulation helped them develop a better understanding of pathophysiology and clinical skills, especially related to respiratory distress. Role and responsibility awareness was also improved for one student (n = 1) by gaining clarity on their duties within a clinical setting. Participants (n = 6) also expressed that this IVR simulation was a valuable learning tool that helped reinforce their clinical knowledge and skills.

Table 1

Descriptive data of the RDMKT[a] scale and SET-M[b] Learning & Confidence subscales (n = 30)

Measure	Mean	Median	SD	Skewness	Range of possible responses	Range of collected responses	Internal consistency coefficient
RDMKT[a] scale at pre-test	4.07	4	1.55	-0.12	0-10	0-7	0.2
SET-M[b]: Learning subscale	10.6	11	1.79	-1.66	0-12	5-12	0.75
SET-M[b]: Confidence subscale	9.93	12	2.56	-1.66	0-12	2-12	0.75

Notes. [a] RDMKT = Respiratory Distress Management Knowledge Test. [b] SET-M = Simulation Effectiveness Tool – Modified.

Table 2

Distribution of the students' (n = 30) responses to SET-M[a] subscales survey questions

SET-M[a] Survey Question	Strongly Agreeing n (%)	Somewhat Agreeing n (%)	Do Not Agree n (%)	Not applicable n (%)	Missing Data n (%)
Learning Subscale					
I am better prepared to respond to changes in my patient's condition.	25 (83.3%)	5 (16.7%)	0 (0%)	0 (0%)	0 (0%)
I developed a better understanding of respiratory distress pathophysiology.	24 (80%)	6 (20%)	0 (0%)	0 (0%)	0 (0%)
I am more confident of my nursing assessment skills.	25 (83.3%)	5 (16.7%)	0 (0%)	0 (0%)	0 (0%)
I felt empowered to make clinical decisions.	23 (76.7%)	7 (23.3%)	0 (0%)	0 (0%)	0 (0%)
I developed a better understanding of medications. (Leave blank if no medications in scenario).	16 (53.3%)	11 (36.7%)	3 (10%)	0 (0%)	0 (0%)
I had the opportunity to practice my clinical decision-making skills.	27 (90%)	3 (10%)	0 (0%)	0 (0%)	0 (0%)
Confidence Subscale					
I am more confident in my ability to prioritize care and interventions.	24 (80%)	6 (20%)	0 (0%)	0 (0%)	0 (0%)
I am more confident in communicating with my patient.	16 (53.3%)	10 (33.3%)	4 (13.3)	0 (0%)	0 (0%)
I am more confident in my ability to teach patients about their illness and interventions.	17 (56.7%)	9 (30%)	3 (10%)	1 (3.3%)	0 (0%)
I am more confident in my ability to report information to the healthcare team.	24 (80%)	6 (20%)	0 (0%)	0 (0%)	0 (0%)
I am more confident in providing interventions that foster patient safety.	23 (76.7%)	4 (13.3%)	2 (6.7%)	1 (3.3%)	0 (0%)
I am more confident in using evidence-based practice to provide nursing care.	20 (66.7%)	9 (30%)	1 (3.3%)	0 (0%)	0 (0%)

Note. [a] SET-M = Simulation Effectiveness Tool – Modified.

DISCUSSION

Our results suggest that despite participants' high mean CGPA score of 3.68, the IVR simulation in this study elicited a statistically significant change in nursing students' respiratory distress management knowledge scores. This finding suggests the preliminary effectiveness of this IVR simulation in enhancing critical clinical skills beyond theoretical knowledge. Participants reported feeling better prepared to respond to changes in their patient's condition and more confident in their nursing assessment skills and clinical decision-making abilities related to COVID-19-induced respiratory distress recognition and management. These preliminary results indicate that the immersive nature of IVR simulations could significantly contribute to experiential learning.

While there are no universally established thresholds for high scores on the SET-M in the literature, our findings align with studies by Brown et al. (2023) and Hoffman et al. (2023), which also support the effectiveness of IVR simulations in enhancing nursing students' learning and confidence. Additionally, our study's high perceived confidence scores are congruent with results from other studies indicating increased confidence in managing critical conditions such as cardiac arrest (Buttussi et al., 2020) and septic shock (Adhikari et al., 2021). Similarly, the high perceived learning scores in our study align with findings that IVR simulations foster learning in basic life support training (Aksoy, 2019).

One significant implication of our study is the role of IVR simulations in bridging the gap between theoretical knowledge and practical skills. IVR simulations provide a safe, controlled environment where students can repeatedly practice and refine their skills, leading to better preparedness for real-life clinical situations. This is particularly relevant in the context of COVID-19-induced respiratory distress, where the rapid deterioration of the patient's condition necessitates prompt and effective clinical responses.

Our study also adds to the merit of IVR simulations in enabling nursing students to identify their strengths and areas for development (Adhikari et al., 2021; Buttussi et al., 2019; Chang & Lai, 2021). This self-awareness is crucial for ongoing professional growth, aligning with the CNO competency of engaging in ongoing learning (CNO, 2018). By participating in IVR simulations, students can reflect on their performance, receive feedback, and make targeted improvements, ultimately enhancing their clinical competence and confidence.

Limitations

While our initial findings indicate a potential benefit of using IVR simulation to provide nursing students with an experiential opportunity to manage respiratory distress, further studies with a larger sample size and additional validated tools are necessary to fully demonstrate the effectiveness of this IVR simulation. The use of additional tools that measure the primary outcomes expected from the IVR simulation and presenting robust psychometric properties is needed. Other limitations include small sample size, no comparison group, single site, and one-time intervention administration. Therefore, no conclusions related to the generalizability of the findings can be postulated. Future research could focus on multi-site retesting of this IVR simulation with the inclusion of a control group and measuring the outcomes of interest (learning and confidence) at both the pre-test and the post-test. Examining associations between outcomes of interest as suggested by Cook (2010), as well as mediating or moderating variables and their impact on the long-term retention of skills and knowledge, might also aid researchers in developing and facilitating future IVR simulations.

CONCLUSION

IVR simulations can be an alternative avenue to expose undergraduate nursing students to COVID-19-induced respiratory distress. IVR simulations in this domain should be structured to help students develop knowledge and skills that can aid them in demonstrating entry-to-practice Registered Nurse competencies that are difficult to access in a real-life clinical setting or develop in the regular in-person simulation labs due to a low degree of immersion into the simulation scenario. This study added to the existing positive findings from the IVR simulation research by demonstrating its potential in increasing students' content knowledge of COVID-19-induced respiratory distress condition and fostering nursing students' perceived learning and confidence in recognizing and managing COVID-19-induced respiratory distress. IVR can be a suitable educational tool to expose nursing students to a high-risk and high-stress environment (requiring immediate action) in a manner that is safe for both a patient and a nursing student.

Authors' contributions:

CC and KN provided substantial contribution and guidance in study conceptualization and design and supervised data collection and analysis. HY developed initial conceptualization of this study, collected and analyzed data, and prepared the first draft of the manuscript. CC and KN revised the manuscript critically for a significant intellectual contribution and approved the final version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of it are investigated and resolved in an appropriate way.

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Statement of conflict of interest:

The authors declare no conflict of interest.

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