2025 ASEE Northeast Section Conference, March 22, 2025, University of Bridgeport, Bridgeport, CT, USA.

Engineering Solutions in Healthcare Training

A Scoping Review of Virtual Reality in Clinical Nursing Simulation

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***Abstract*—Real-life clinical simulation is a fundamental aspect of undergraduate nursing training. It allows for student nurses to experience close to real scenarios in a controlled environment. However, clinical simulation spaces require a large investment to build and maintain, making it inaccessible in lower resource institutions. Virtual reality in nursing education has seen increased implementation in curriculum within the last decade. The purpose of this scoping review is to examine the current literature surrounding virtual reality head-mounted displays in nurse training. Of 31 articles examined, current implementations of virtual reality primarily focus on teaching technical skills (n = 19), while immersion (n = 6), soft skills (n = 6), and other topics (n = 5) have also seen deployments in the field. This technology has shown potential in knowledge acquisition (n = 8), self-efficacy (n = 9), engagement (n = 8), and satisfaction (n = 6) among users. Future work should look at how soft skills and immersion are being taught using virtual reality, and how smartphone-based virtual reality head-mounted displays can be used to provide a low-cost and portable means to access nursing simulation content.**

Keywords—Virtual Reality; Simulation; Nursing Education; Digital Technology; Head Mounted Displays

I. INTRODUCTION

One of the Grand Challenges of Engineering for the 21st Century is to enhance virtual reality (VR) technology to solve problems in our society [1]. Healthcare remains a huge cost driver in our society; costs are expected to increase with the aging of the baby boomer generation [2], [3], and there is a reported shortage of nurses to care for this population [4]. A persistent challenge within healthcare is the effective training of nurses, not only to provide future nurses with the necessary skills to do their job, but also to reduce early career burnout.

A common method to prepare future nurses for the rigors of the clinic is to provide real-life simulation laboratory (Sim-Lab) experiences where training institutions create simulated, real-world, healthcare spaces with accurate equipment, simulated patients, and experiences to what would be experience in the clinic. VR, and specifically VR head-mounted displays (VR HMDs), have potential to provide these types of immersive clinical training experiences at a lower cost than traditional Sim-Labs (Fig. 1.)

Fig. 1. Oculus Quest 2 VR HMD

One potential cause of early career burnout among nurses is the theory-practice gap. Within nurse training, the theory-practice gap describes the difficulty new practicing nurses encounter when translating the **theories** they learned in their undergraduate classrooms to clinical **practice** as nurses. This gap is defined by the perception that knowledge and application exist in two separate spaces: classrooms as a place of theory, and the clinic as a place of practice [5]. This disconnect can lead to a hesitancy among early career nurses to provide care to patients, or fear the equipment used, leading to an overall drop in quality of care they provide [6]. Additionally, undergraduate nurses in training partaking in clinical rotations may observe practicing nurses using strategies outside or against their academic training in high-pressure situations, further widening the gap [5]. Sim-Labs have the potential to address the theory-practice gap by allowing nurses to apply their formal education to the clinical environment while in training.

Sim-Labs allows students to perform tasks in an immersive clinical environment without the stress and risk associated with the real clinical environment with real patients [7]. Sim-Lab training has proven its effectiveness for both knowledge and skill acquisition [8], and has also been attributed to increased self-confidence among nursing students [9]. The magnitude of skill acquisition among trainees is associated with the fidelity of the simulation, with higher fidelity simulations creating a sense of presence in a simulation environment. Higher fidelity simulations allow nurse trainees to "feel" as if they are in those situations, increasing engagement with the Sim-Lab experience [10], [11].

While well-resourced institutions with dedicated Sim-Lab spaces can provide high fidelity simulation experiences for their students, cost and labor associated with these spaces may be unattainable for institutions lacking financial resources or physical space. Nurses without access to clinical simulation are at risk of being less prepared compared to their counterparts using Sim-Labs [12]. 65.2% of registered nurses earned a baccalaureate or higher-level degree, while the remainder received either an associate's degree from a community college, or a potentially low-resource institution, or institution serving primarily underserved populations [13]. Therefore, while high fidelity simulations represent an important approach for training future nurses, the cost and expertise required to build and maintain these spaces may not be feasible for all training institutions.

One potential approach to make clinical simulation experiences more readily available to nurses in training is with commercially available VR HMDs. VR refers to any computer-generated, three-dimensional interactable environment [14]. VR HMDs are head-mounted displays that provide imagery in a simulated environment that change in response to a user's head movements [15]. Computer-based VR differs from VR HMDs as the user is not directly interacting with the virtual world with movements [16]. While some headsets require "tethers" or external computers to work, recent developments have seen a push more towards "un-tethered" HMDs, especially as the technology becomes more accessible as a whole.

II. METHODS

The purpose of this study was to evaluate the state of the field of applying VR-HMDs within nursing training. We performed a scoping review on how VR HMDs are being applied in academic institutions to train nursing students. We performed a search across PubMed and EBSCO with the following keywords: "virtual reality," "simulation," "nursing education," "head-mounted display," and "digital technology."

Literature Search Strategy

Only full-access articles from peer reviewed journals published in English were reviewed in this search. Potential articles were stored in a separate document for further review, and were vetted based on the following criteria:

1. Is the article in English?
2. Is full access to the text possible?
3. Is the title and/or abstract relevant?
4. Is it a review article?
5. Does the article specifically reference nursing students?
6. Does the article specifically reference VR HMDs?

Review articles were excluded from consideration, as the focus of this paper was to determine current applications in the field. Figure 1 shows a Sankey Diagram visualizing the review process (Fig. 2.)

Accepted papers were divided into the following categories to guide our review:

- Which Modality was being taught? (Technical skills, soft skills, immersion, or other);
- How was the simulation evaluated? (Pre- and post-intervention tests, Likert-surveys, etc.);
- What activity was the focus of the simulation?
- What significant outcomes were reported?

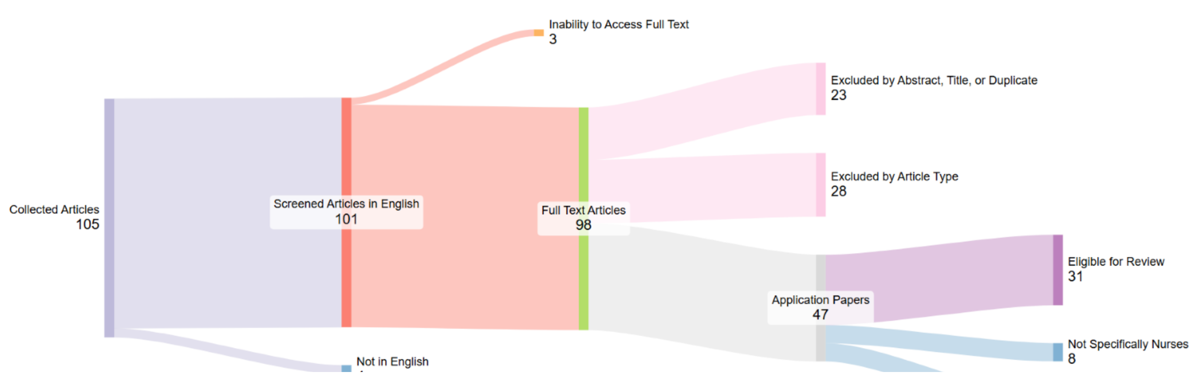

Fig. 2. Visualized Review Process

III. Results

In total, 105 articles of interest were identified as part of this review, with 31 articles involving 2802 nursing participants fitting into the criteria described above. A table summarizing the 31 studies can be found in Appendix 1.

Current applications of VR HMDs in nursing education have shown promising results to supplement traditional simulation. Across noted activities reviewed, such as practical tasks, patient interaction, and surveys, there was a positive response to these technologies, with nursing students recognizing the importance and potential of HMDs in their field [17]. Additionally, students reported feeling more engaged with VR HMD simulation as compared to screen-based simulation experiences [18].

Most of the current applications of VR HMDs are technical (n = 19), with immersion (n = 6), soft (n = 6), and other (n = 5) applications making up the remainder (Table 1.)

Technical Skill Papers

Technical skill papers focused on teaching participants skills through the active involvement and interaction with the VR space and patient. These activities are more tactile in nature; participants use the VR HMD controllers and move around a space to accomplish a certain task. Technical papers often involved teaching students about infection control [19], [20], [21], [22], chemo port insertion [23], tracheal suction [24], catheterization [25], [26], or tube feeding [27]. Additionally, some technical papers focused on the operation of ventilators [28], [29], pressure ulcer management [30], IV therapy and surgical competency [31], [32], resuscitation [33], treatment of a patients with hyperglycemia, asthma, or pediatric patients [34], [35], [36].

Soft Skill Papers

Soft skill papers focused more on teaching nursing participants how they should interact with a person or the clinical space without engaging in a technical activity. VR HMD use in this case allows for nurses to experience situations they may perceive as stressful (interacting with aggressive patients or patients with mental illness). Soft skill papers often involved teaching students about interacting and communicating with patients with a deteriorating condition [37], applying clinical judgement while interacting with virtual patients during routine clinical care [18], [38], or how to communicate with patients ready to be discharged [28].

Immersion Papers

Immersion papers describe real-world scenarios recorded by a 360° camera. This camera was either located in the space of practice, or was directly mounted to the nurse using a harness or headband. This allows the viewer of the video to imagine themself directly playing the role of the practitioner they are watching, allowing them to learn how to interact in different scenarios. These papers often involved immersing viewers in surgical environments [39], watching how nurses directly interact with patients suffering from schizophrenia or other mental illnesses [40], [41], [42], or tutorials of procedures specific medical procedures, such as tracheal suctioning [24], [43].

Other Papers

Finally, "other" papers described papers that didn't fit into the above categories. These involved studies on cybersickness [44], a proof of concept on caring for a patient with Alzheimer's [45], using VR HMDs to immerse students in an anatomy and physiology course [46], or surveys about how nursing participants viewed immersive VR experiences [17], [47].

Evaluations

A common style of evaluation among the selected papers was comparing a participant's knowledge before and after the intervention via a pre- and post-test (n = 6). Additionally, Likert-based surveys were another common way to gauge personal responses to the intervention outside of knowledge (n = 19), as were interviews conducted by the researchers (n = 5). Professional evaluation in a supervised clinical setting were also used to gauge proficiency (n = 5). Finally, some articles used more specific evaluations depending on the focus of the study. These were the NASA-TLX and SUS Questionnaire (n = 1), BES-A, CSES, and AttrakDiff 2.0 (n = 1), Virtual Reality Sickness Questionnaire (n = 1), Perceived Engagement Survey (n = 1), or OSCE Assessment (n = 1).

Modality Taught	Outcomes Measured			
	Knowledge	***Self-Efficacy***	***Engagement***	***Satisfaction***
Technical	4	4	6	5
Soft	2	3	1	0
Immersion	2	2	1	1

Table 1. A comparison between the modalities taught in the simulations and which outcomes were measured.

Common Outcomes

Increased satisfaction in learning was a common outcome among experimental groups [19], [20], [22], [23], [27], [39], [47], as was increased knowledge among participants [23], [30], [31], [35], [38], [41], [42]. Self-efficacy, confidence, and increased reasoning/judgment were also a common outcome in experimental groups [19], [29], [31], [35], [38], [41], [42]. Immersion and engagement were another commonly reported outcome, with both metrics being significantly different compared to control groups [18], [20], [21], [24], [25], [33], [39], [43], [46] (Fig. 2.).

In terms of specifically measured outcomes, VR was noted to invoke a favorable level of empathy for patient interaction [37], detection of pressure ulcers [30], catheterization [25], [26], and pediatric care [36]. Additionally, surveys conducted to gather general nursing opinions on the technologies produced favorable results and were welcoming to this technology in the future [17], [47].

IV. Discussion and Conclusion

While Sim-labs are an important tool in training nurses to address the theory-practice gap, the high cost for both the creation and maintenance of these spaces can be cost-prohibitive. Advances in VR technology and VR HMDs has opened an opportunity to create new, lower cost, clinical immersion experiences that could be used in nursing training to provide immersive clinical experiences.

We identified a total of 31 relevant studies in our search, with the majority (n = 19) focused on teaching specific technical skills. We believe that VR HMD use in nursing education favors technical skills due to the nature of the technology and the simulations that are currently available for use commercially. Though communication with patients in this technology is possible, it often occurs through selectable text options, not necessarily an active dialogue between the virtual patient and nurses.

Perhaps the greatest strength of VR HMDs relative to screen-based VR experiences is adding to sense of presence within the simulation [48]. By definition, presence is the state of being in interaction with the physical world [49]. This phenomenon often falls under the metric of "immersion" or "engagement," and describes the feeling of "being" in the simulation. A sense of presence is potentially important to address the theory-practice gap, as allows the subject to feel that they are applying their academic skills in a real-world environment in practice. An increased sense of presence in nursing simulation makes it so the participant begins to feel a sense of responsibility and care for their patient, regardless if they're an actor or manikin [50]. A sense of presence is important when conducting nursing simulations, as the perceived presence of the participants has been shown to positively affect learning outcomes [51]. As such, it is important that future simulations work to create spaces that are immersive to provide the best possible outcomes for their participants.

Importantly, most to all these studies occurred at relatively well-resourced institutions with the available infrastructure and research personnel to deploy these interventions. Novelty bias can partially attribute itself to some of the positively self-reported outcomes as described above [52]. Novelty bias describes the phenomenon where an intervention is more attractive because it is new. Reported feelings of anxiety were reported around first-time VR HMD users [32], and although this feeling went away after repeated trials, it may take time for users to become comfortable with using the device. Among cultures with high technology use, VR HMD technology was seen as attractive and important for their learning, however this group also has the greatest exposure to the intervention as compared to areas with lower technology use.

Finally, cybersickness remains one of the biggest obstacles to VR HMD use, and was showcased rather directly in an article comparing VR HMDs to traditional simulation [24]. Cybersickness manifests as motion sickness-like symptoms and is caused in part due to the visuals in VR simulations and the lack of physical movement relative to movement of what one perceives [53]. Additionally, cybersickness was reported to have a greater effect on women as compared to men, an important factor considering the demographic breakdown in the nursing profession [54]. Though cybersickness is an effect that goes away with repeated use of VR HMD technology [44], it is a factor to keep in mind when conducting research or using this for at scale deployment of the technology. Currently, there are no best practice strategies in place for dealing with cybersickness, and future studies should focus on researching this phenomenon to allow for the technology to see widespread implementation.

VR Device	Occurrences	Cost at Release
BNext HMD	1	$50
Oculus Quest	3	$399
Oculus Quest 2	6	$299
Oculus Rift	1	$599
Oculus Go	2	$199
HTC Vive	6	$799
HTC Vive Pro	1	$799

Table 2. Headset Costs and Occurrences (Note: 11 papers did not directly specify the VR HMD used in the study)

Relative to a Sim-Lab, VR HMDs require a small initial investment (Table 2.) Additionally, the ease of use, and flexibility of programming makes this technology incredibly attractive [55]. Currently, 65% of nursing programs use some form of virtual simulation, such as VR experiences and videos, in teaching [56], but there is a clear gap in literature involving the use of VR HMDs in nurse education [57]. As such, VR HMDs can potentially ameliorate the theory-practice gap by allowing nursing trainees the ability to immerse themselves in a simulated clinical environment without the space and cost associated with a Sim-Lab.

A way to expand access to the Sim-Lab can be by utilizing smartphone-based VR HMDs to a greater extent for immersion activities. As smart-phones have become ubiquitous consumer items, with at least 98 percent of college students possessing them in 2024 [58], low-cost ($15) adaptors such as the Google Cardboard, could be leveraged to turn smart-phones into mobile VR-HMDs. Interestingly, Smart-phone-based VR HMDs were only used by 3 papers found in this review. These offer an interesting opportunity for 360° camera activities to be experienced by students anywhere, potentially significantly improving access to immersive training experiences. The use of smartphone-based VR HMDs in nursing education remains a clear gap in the literature and represents an important step in implementing this technology at scale in the future.

Due to the perceived and measured benefits of VR HMDs currently being used in nursing education, it is important that adequate support and resources be provided to further facilitate the development of these technologies. Engineers are uniquely positioned to partner with nursing professionals to create simulations based on gaps of knowledge or feedback from clinical practice, ameliorating the gap that exists between theory and practice currently within nursing education.

Acknowledgment

This work was funded through the School of Engineering and Computing at Fairfield University and the Sapre Aude Fund. We would also like to thank the Egan School of Nursing for their collaboration on this project.

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