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A Review of Contemporary Practices for Virtual Learning within Medicine

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ABSTRACT: The need for more practical environments for learning is stressed within the area of medicine. An innovative but complicated strategy that professionals may decide to test is virtual reality (VR). More needs to be done to help students be more prepared and equipped with solving professional issues, not just in theory. To improve VR use within medicine, one must know the trends as well as the gaps within existing research. This review covers innovative techniques and trends for virtual learning environments to help medical students and practitioners get more training and guidance in higher education. It identifies common trends for research concerning medical education and recommends ideas for further exploration of VR as a versatile learning environment.

KEYWORDS: Virtual Learning, Virtual Reality, Medicine, Higher Education, Technology

INTRODUCTION

The use of virtual reality learning environments (VRLEs) is not stopping anytime soon (Iqbal et al., 2024; Kafes & Ileri, 2025; Kapoor et al. 2025). In fact, it is still growing. For instance, the medical field has more educational options that involve a virtual environment. But are those environments useful, or are there more to be desired? There is a need for more standardization and innovation within the medical field since there is no shortage of disease and injury in the world. Not to mention there are new developments and changes happening to address problems locally, nationally, and globally. On a local scale, individual medical professionals must deal with the practical demands of their work. Nationally, there are high costs to U.S. health care as well as financial strains on health systems. On a global level, there is the need to address the economic devastation of epidemics and pandemics. Practical solutions in technology are a feasible option given that vaccines, equipment, and practical treatment must involve either tangible or intangible ideas (Djellal & Gallouj, 2005; Mayrink et al., 2022). When people are looking for solutions in medicine and healthcare, they are not looking for delays, setbacks, excuses, and constraints, especially when lives are at stake. Practical acumen and education save lives, time, money, pain, mental anguish, and lawsuits. Within the areas of medical education, the training involved must be not only engaging but more diverse to attract those interested enough in medical study to develop the expertise required for successful treatments and procedures. A VRLE may be able to provide the engagement and diversity that the medical field needs, where trainees can be immersed into settings they should expect in the real world without the pressure of failure or harm (Howard et al., 2026). It can allow for specific real-time and real-world situations to familiarize trainees with the problems they should solve in their respective areas. However, the medical field is only employing VRLEs in specific ways within specific curricula. To understand exactly where VRLEs have been applied and what directions can be useful for medical education in the future, it is essential to answer the following research questions:

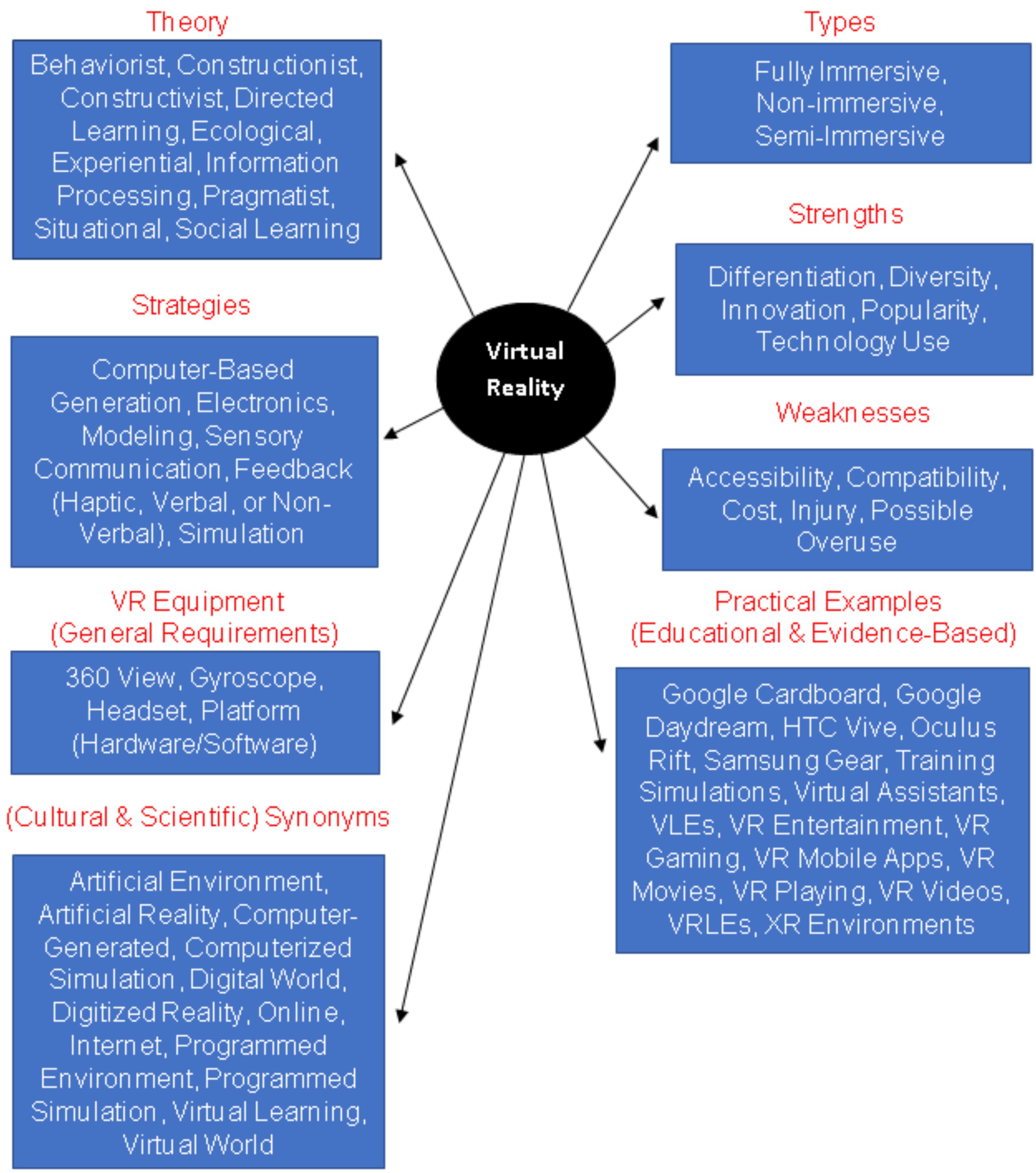
1. What patterns and trends are evident within studies about VRLEs and medicine?
2. Where are VRLEs most effective within these studies?
3. Where are the research gaps concerning the use of VRLEs within and outside of medicine?

Since VR equipment can get expensive and time-consuming, it is important to have specific areas of need identified as well as specific milestones in terms of virtual reality (VR) use in higher education. There are risks to utilizing technology, and those risks need to be reasonably weighed against the benefits. Knowing more information about VR can help address important risks involved as well as what can be done to mitigate those risks (Kourtesis et al., 2019)

SCOPE AND METHODS

A systematic literature review was conducted at the beginning of 2023 with the author and a colleague who taught at the university. Just searching for VR in higher education would not work because databases are inundated with studies about it. This author outlined important concepts within virtual reality and higher education to specify articles dealing with key issues. A conceptual spider map was developed to determine what was available concerning these topics. Database searching occurred within EBSCO Academic Search Complete, ProQuest, and Google Scholar. To search for each relevant term, combinations were used. Each combination started with Virtual Reality + Higher Education. For example, to search for articles on differentiation, the full key terms would be Virtual Reality + Higher Education+ Differentiation. Results were not limited by country. This means that although the ones who conducted the study were in the United States, the results yielded studies within and outside of the United States.

From Academic Search complete, there were 61 articles within the stated parameters. From ProQuest, there were 209 articles. From Google Scholar there was a yield of 181 articles. Because this review is focused on the medical field, the search results from the mapping had to be narrowed down to medical-related studies and/or VR studies that could be freely accessed from the databases. Out of the articles found, a total of 39 studies were medical-related and freely accessible from the databases. Article summaries were made for each study, and a comparison table was created to link the studies together according to certain characteristics (see Appendix A). Microsoft Word was used to create typed summaries of each study, and the summaries were stored within Google NotebookLM to create additional mind maps and organizers to check results. Duplicates were found in the references from the software check performed, and duplicate studies were removed within the comparisons. The concept map in Figure 1 was created by the author using Microsoft Word.



KEY STUDIES

Modern day medicine requires the use of technology. To reach medical students of today, VR use is encouraged to help them know and apply important concepts. Based on the studies that were found that address medical education and medical treatment, the studies discovered covered four major areas of application for VR: (a) Learning Comparisons and Effects; (b) Medical Training; (c) Social Experiences; and (d) Therapeutic Strategies.

LEARNING COMPARISONS AND EFFECTS

Most of the studies (*n* = 13) pertained to outcome comparisons and medical side effects. For medical learning outcomes, notable learning equipment involved the HTC Vive Pro, (ProMIS), (MIST-VR), MedChemVR, or (LapSim). In terms of outcomes, VR was found to be the preferred engagement activity for learning over traditional medical learning methods, such as lectures, textbooks, and paper-based case studies (Fabris et al., 2019; Fernandez-Arias et al., 2023; Singleton et al., 2022). Participants found VR to be more interesting when it felt authentic to what was being learned or when it was personalized to the learning needs of the participant (Fernandez-Arias et al., 2023). VR interactivity did not guarantee significant gains in engagement, particularly when compared to AR methods. For instance, laparoscopic suturing was explored by Botden et al. (2007) where an augmented reality (AR) simulator (ProMIS) for laparoscopic basic skills and suturing was compared to a VR simulator (LapSim) about the same subject matter. The 90 subjects preferred the AR simulator in their overall ratings as it provided more realism and interaction with objects. When interactivity was incorporated within movies or videos, there were instances of increased test scores (Botden et al., 2007; De Faria et al., 2016). Although improved engagement was a consistent outcome for many studies, learning gains were more variable. Most studies indicated direct relationships between VR use and medical knowledge acquisition (Kumar, 2023). Kumar (2023) determined that there was a direct correlation between VR simulator use and medical knowledge. Students were generally more satisfied, less anxious, and more informed, especially when having to use VR as a learning alternative during the COVID-19 pandemic. Abuhammad et al. (2021) supports Kumar's findings with his study on the pharmacy game MedChemVR. Pharmacy students were more engaged and memorized more about drug molecules than they had before the VR intervention. Singleton et al. (2022) further found that nursing students had higher test scores, engagement, and confidence with non-immersive VR when compared with a group that used paper-based case studies to learn about Type 2 Diabetes and hypoglycemia. According to a study by Fabris et al. (2019), however, knowledge gains were about the same between VR and traditional methods Equipment could also be a factor in how well students learn. Zhou et al. (2012) compared a haptic (ProMIS) and non-haptic (MIST-VR) simulator for laparoscopic suturing to practice knot tying. The haptic simulator showed more learning gains within the first 5 hours of use, but these differences did not last after 5 hours.

For medical side effects, studies generally indicated nausea, dizziness, or cybersickness when dealing with prolonged exposure to VR (Chang, 2021; Detyna & Kadiri, 2020; Martirosov et al., 2022). They may or may not have been directly related to the medical field, but medical concerns were reported to encourage more research, regardless of subject matter. The more immersive the VR, the more likely a participant would have medical side effects. (Martirosov et al., 2022). Malinska et al. (2015) added to these effects increased heart rate variability and sympathetic performance. These can be viewed as positive effects for the study involved, but it was also reported that participants had fatigue and hand pain when virtual workstation tasks were too repetitive. Martirosov et al. (2022) further noted a decrease in oculomotor function when completing routine virtual tasks over time. Finally, Moro et al. (2017) found that 20 health science students experienced more disorientation and blurred vision with the Gear VR mobile when learning about spine anatomy. This was less likely to happen from the desktop version of the Oculus Rift, which students found more user friendly.

MEDICAL TRAINING

There were several studies (*n* = 8) about medical training, separate from causal-comparative methods, that ascertain the effectiveness of VR within that specific area. Applications for simulators can vary, with the equipment requiring either a computer, special VR equipment, mobile technologies, or a combination of these. From a conceptual standpoint, combination methods for instruction are encouraged where feasible, within and outside of the area of medicine. **(**Haluck & Krummel, 2000; Morimoto et al., 2022). Haluck and Krummel (2000), for instance, found in their review that VR-based surgical education provided safety, affordability, and efficiency that traditional methods did not. They included flight simulation research to argue that simulation training reduces the learning time when compared to live training; however, a combination of simulated and live practice would help people to be more adept within different training contexts, especially when finding innovative ways to learn surgical skills. This combination method is also in congruence with positive and negative results found from a narrative review from Morimoto et al. (2022) that discussed extended reality in spine medicine, including VR within the discussion. Overall, it was found to be possible to improve surgical accuracy in an affordable and realistic way while also reducing radiation issues, but side effects included fatigue over long period of time. More VR tasks could increase the workload demand if not addressed in a practical manner that would improve the training schedule.

Moreover, the use of haptic feedback within medical training was highly recommended. Alaraj et al. (2015) found that a haptic-based ImmersiveTouch VR simulator helped participant neurosurgeons realistically learn about surgical techniques concerning cerebral aneurysm clipping. They found it useful training, but there were difficulties concerning depth perception and technical mechanics of the aneurysm clip that affected how realistic it could be. Haptic feedback was further explored within Lemole et al. (2007) and Vapenstad et al. (2013), where it was realized that haptic feedback must be realistic enough to have construct validity and practical relevance for those in surgical training. The difference between studies was that Vapenstad discovered a simulator (LapSim) with limited validity, whereas Lemole worked with a simulator that was valid and effective for neurosurgical education (ImmersiveTouch).

One final, important discovery within the medical training studies was that some studies focused specifically on cardiac-related training and planning. Almousa et al. (2019) developed a VR system for CPR training that was tested by 20 participants. The VR system, which used HTC

Vive and Unity 3d, involved medical scenarios with haptic feedback and gamification features. The participants were highly engaged with the VR system, and this engagement increased the most times they were exposed to the system. Garcia Fierros et al. (2021) had an Android version of CPR training where participants with prior training had more accuracy on the 3D simulation. Napa et al. (2019) utilized the Bosc and Medical Holodeck VR apps to evaluate their effectiveness for cardiac surgery planning. The eight surgeons who participated preferred the Medical Holodeck for planning due to its clear organization structure and ease of use.

SOCIAL EXPERIENCES AND SOCIAL JUSTICE

From the search, there were 10 studies about social skills in medicine, social behavior, social justice, and non-traditional environments. For social skills, Sapkaroski et al. (2018) discovered that radiology students who used a haptic-based simulator (CETSOL VR Clinic) were able to improve their communication and positioning skills in ways that were preferred by the students. Those who used a non-immersive simulator had a lower level of improvement did not show as much improvement. Social behavior testing was experimented on by Lobbestael & Cima (2021), particularly in aggression. Participants experienced two VR tasks within a simulated bar scenario and simulated alley scenario. They wanted to see how well aggression could be detected using the VR scenarios. It was found that reactive aggression could be directly linked with systolic blood pressure, but there was no valid basis for proactive aggression. Tacgin (2020) also used VR (myVOR) to document and determine behavioral and attitude-related changes in 14 nursing students. The immersive VR setting helped them learn more about preoperative procedures, have more curiosity, and have more self-confidence; however, the program was only effective when hints and learning aids were presented with the VR content. Gunn et al. (2021) noticed that within two survey studies there was more clinical confidence for medical imaging and radiation therapy students when they use computed tomography VR simulations for practice. They were more engaged with VR, but it was also noted that they preferred guided learning with an expert over self-directed virtual learning methods. For social justice, there were two empirical studies that delved into medical conditions in relation to social rights. The human condition and the practical treatment of animals in research would be of medical concern. For technology to be relevant, it must be easy to use, convenient, and relevant to the point that it does not cause fears associated with technology. For instance, McFaul & FitzGerald (2019) found that 60% of undergraduate law students who had access to the Open Justice smartphone app to explore virtual environments did not engage with it because of time limitations and technological anxiety. Another example can be found with Vea (2019) conducted an ethnographic study where 360-degree video and VR were used to make people aware of animal mistreatment and how emotionally heartbreaking these situations can be. Vegans and vegetarians became more active advocators of this issue.

In addition, VR may be needed in a supplementary or non-traditional way for students not to be distracted. To help students learn, the amount of VR may need to change according to context. The number of people involved within the experience may also need to change. Tolsgaard et al. (2015), for example, found that peer group training, also known as dyad training for the study, was more efficient for ultrasound simulation training than individual training. Medical students learning in dyads were able to transfer skills from the simulator to clinical practice at higher rates and pick up on their mistakes more readily than those who performed individually. Peer learning was also preferred within an experiment from Sancho et al. (2009) that contained a multiplayer role-playing game to teach computer programming in a laboratory setting. Although many of the students rated the 3d gaming experience well within their gaming teams, they would have preferred to play with friends. Although the results of Sancho et al. (2009) may not be directly related to anyone in the medical field, the strategy addresses the need for more collaboration in laboratory settings. This encourages more study concerning comparisons within and between different contexts, approaches, fields, and medical environments. Collaborative learning was also emphasized in a pilot study with Heid & Kretschmer (2009) for the LLL3D project, which involved establishing virtual communities in Second Life. This is recommended for a flexible environment that may meet educational demands in a deregulated way. Johnson et al. (2009) took this further by exploring the use of Second Life with nursing informatics students at Duke University. Synchronous learning, active learning, teamwork, avatar presence, and social interaction were part of the exploration, and students rated the virtual method more positively than traditional methods.

THERAPEUTIC STRATEGIES

Finally, eight studies about VR have looked at the extent to which simulations can be useful for psychological testing, wellness, and treatment. For neuropsychological testing, Kourtesis et al. (2021) used the VR Everyday Assessment lab to test memory and attention, and it was more valid and enjoyable for participants than traditional paper and pencil testing. Howard & Van Zandt (2021) conducted a meta-analysis of 137 studies that assessed gender, age, neurological disorders, and motion sickness susceptibility. They found that there were direct correlations between VR sickness and gender (i.e., females tended to be more sick), motion sickness susceptibility, and neurological disorders (e.g., phobias). Frederiksen et al. (2020) also indicated there tends to be higher cognitive load, lower performance, and higher mental demand at more immersive levels of VR. For laparoscopic surgery training, it is recommended that students master skills with more traditional (less immersive) VR simulation techniques before being introduced to more immersive options.

In terms of well-being and treatment, there are a wide range of conditions that have been addressed. Hoffman et al. (2011) reviewed multiple studies on the extent to which VR could serve as an analgesic, particularly for burn patients. In order for this to occur, patients would be shown an enjoyable distraction, such as a snowball fight, that would reduce pain signal processing whenever medical procedures needed to be done. Tractenberg et al. (2007) explored survey research about attitude changes during a Mind-Body Medicine course. It was found that subjective ratings showed more significance in attitude than what was statistically recorded, showing the need for diverse methods of measurement within the areas of psychological well-being and management. Cesa et al. (2013) studied how 66 female obese patients with binge eating disorders reacted to body image and weight loss within three treatment groups: a VR-enhanced cognitive behavioral therapy (ECT) group, a traditional therapy group, and a standard inpatient care group. Those who were in the VR group had the most significant improvements in terms of body image and weight loss management. Lee et al. (2021) used self-introduction scenarios within a virtual environment to address the needs of 28 patients with social anxiety disorder. The VR therapy was an effective treatment for the patients, and this was indicated by a measurable increase in prefrontal cortex activity during the social scenarios presented. Finally, Modrego-Alarcón et al. (2021) practiced mindfulness-based interventions (MBIs) with university students. It was discovered that those who received VR support along with MBIs had significant stress reduction and increased academic functioning over time.

DISCUSSION

Based on the results of the 39 studies, there are several key patterns concerning VR research and practice. First of all, many VRLEs within medicine pertained to surgical procedures (Botden et al., 2007; De Faria et al., 2016; Frederiksen et al., 2020; Napa et al., 2019; Haluck & Krummel, 2000; Lemole et al., 2007; Zhou et al., 2012) Medical professionals tend to use VR simulations as a way to acquire or practice skills that are useful within a clinical setting. There is a need for VRLEs to be as practical as possible to make it easier for students to acquire skills in comfortable ways. Different perspectives within a learning environment can facilitate this learning as long as it is intuitively easy to follow. It has to make sense to the user more than it does the manufacturer or the developer. A creator of VRLEs, therefore, needs to have a good understanding of what works for those within the medical community. Software should have updates with this in mind.

VR use generally shows more participant engagement, regardless of whether it is used as a main part of a lesson or as a supplementary part of the lesson (Abuhammad et al., 2021; Almousa et al., 2019; De Faria et al., 2016). Learning gains, however, are not as consistent as engagement gains. The more personalized and realistic a simulation is, especially within the medical field, the more students can benefit in terms of learning and training (Alaraj et al., 2015; Almousa et al. 2019; Hoffman et al., 2011). Team-based activities and guided activities tend to be more engaging than self-directed activities, but the learning gains could be limited if learning preferences are not considered to a certain extent (Gunn et al., 2021). There are technical learning hinderances to consider as well. Too much prolonged immersion without any breaks or different activities can have serious side effects, including but not limited to nausea, cybersickness, dizziness, mental overload, and lower performance (Chang, 2021; Detyna & Kadiri, 2020; Fabris et al., 2019; Frederiksen et al., 2020; Howard & Van Zandt, 2021; Morimoto et al., 2022; Moro et al., 2017). With high quality, well-designed VR systems, total duration can range from 55-70 minutes if participants are adequately familiar with it before sessions begin (Kourtesis et al., 2019). If the practical situation is less than ideal, the amount of exposure to the environment would suffer. There would need to be backup plans or other strategies available for learning if someone cannot handle the VRLE after a certain period, and this amount of time can vary. Also, those who do not have prior knowledge of how to handle VR equipment would have a worse time navigating it than those who do (Fernández-Arias et al., 2023; García Fierros et al., 2021). This suggests that effective pre-session training and professional development are crucial before actual implementation.

Although there are concerning side effects with VR exposure, it is also common to see VR used as a diagnostic evaluation and treatment method for patients with social, emotional, or behavioral problems. VRLEs can assist users with increasing their confidence, lessening social anxieties, increasing mental function, cooperating with others, increasing weight management, and identifying stressful triggers (Cesa et al., 2013; Heid & Kretschmer, 2009; Hoffman et al., 2011). If a VRLE is likely to be user-friendly across different fields of study, then more innovative, afforable options could be available for personal and professional development (Fernández-Arias et al., 2023; Haluck & Krummel, 2000). For instance, the use of an MMORPG or a mobile app could make a virtual experience more accessible. More access means more opportunities for practice. Diverse practical scenarios within a VRLE would help with how well it is received (Johnson et al., 2009). Access does not always lead to effective utilization, so it is important that the software accessed is also software in actual demand (McFaul & FitzGerald, 2019). Otherwise, professionals could waste copious amounts of time and money on something that few people desire to use. The more VR is tested, the more determinations can be made as to how well it would be received within the medical community (Kourtesis et al., 2021; Sapkaroski et al., 2018). If there is a problem implementing it within the medical community, then other fields could provide an option for implementation and testing. Having VRLEs incorporated across subject areas would help in terms of social interaction and therapy, but the more technical, specific skills within medicine would necessitate more direct, field specific uses of VR. The study of symptoms within VRLEs could involve both field-specific and field-versatile environments (Kumar et al., 2023; Tolsgaard et al., 2015) Therefore, educators and professionals need to consider their learning goals and intentions before picking a VRLE-based activity to implement.

Based on the studies discussed within this review, there are research gaps that exist within VR use. It is possible more studies exist to lessen the potential significance of these gaps, but areas of improvement still need consideration to determine how VRLEs can be more realistic in terms of implementation. One area that needs consideration is how VR motivation and personal VR preferences affect outcomes. Is it possible that personal preferences can get in the way of learning? If VR is very enjoyable, does the student with the most engagement do better than someone who may have moderate engagement? Another area would be its use as a treatment. Are there medical conditions that VR is especially effective at treating? How do those methods compare with already prescribed methods? A third area worth noting is the use of a virtual assistant or VR environment as alternatives to face-to-face interactions, especially during serious illnesses and pandemics. Having an online VR option that expands telehealth services, automation, clinical practice, and professional development could make the medical environment more engaging and comfortable for people who may have issues with a medical facility. Medical-related VR needs to expand its reach beyond surgeries and skills. There are more contexts and dynamics at play when dealing with patients, such as social interactions, proper communications, technology skills, medical reporting, cultural differences, gender-related concerns, condition identification, and treatment options. These areas need more research, particularly regarding mixed-methods approaches. Having mixed methods approaches would allow for more comprehensive observations, assessments, and evaluations concerning VR use within higher education. A final area of consideration is critical thinking. Since technical aspects of learning are more likely to have VR experimentation, there needs to be more development on what to do in difficult, time-sensitive situations. It is not impossible for someone to receive lawsuits about malpractice and surgical errors. How can VR help medical practitioners do well when situations are not ideal? What needs to happen if someone makes a mistake? Practicing in ideal VRLEs may address some practical concerns, but not everything will be as expected. The more experiences professionals have under pressure, where they feel tense, stressful conditions concerning patient needs, the more likely they will be more prepared if something goes wrong or needs more attention than initially thought. It is possible for two doctors to disagree on a diagnosis or a treatment plan. Some programs for treatment may be more accessible to some patients than others. VR designs need to test not only the most optimal situations for learning, but they also need to determine how people can learn and function when the situations are much less than ideal and precision is critical in an already stressed work situation.

CONCLUSION

The use of more virtual options in medicine has a demand that is not waning anytime soon. Through this systematic review, it was discovered that VRLEs have been implemented for a variety of reasons concerning the medical field. Key areas of empirical study for the medical field involve learning outcomes, medical training, social experiences, and therapy. While the areas are diverse in terms of application, the VRLEs themselves need more personalization for participants to get the most out of the experience. There needs to be more exploration for VR in terms of how it can treat medical conditions and address user preferences. It is not enough to use it for recall or demonstration. While there are opportunities to do more with VR, one must keep in mind the practical use for students, patients, healthcare providers, and medical professionals. VRLEs are not limited to just being clinical knowledge dispensers for a university setting. They are worlds of experience for anyone who engages with them in an immersive way. Technology can help cultivate more effective, diverse, and critically minded medical professionals, but this only happens when those in medicine are truly prepared for its practical implications.

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Appendix A

Study Comparison Table

Study	Purpose	Sample	Independent Variable	Dependent Variable	Key Findings
Abuhammad et al. (2021)	To evaluate the MedChemVR game as a tool to enhance medicinal chemistry education for drug molecule study.	41 university students	VR gaming experience (MedChemVR app).	Attitude toward MedChemVR; Effectiveness as a learning tool.	Participants found the game engaging and enjoyable. It aided in memorizing chemical structures.
Alaraj et al. (2015)	To develop and evaluate a haptic-based VR simulator for teaching aneurysm clipping to future neurosurgeons.	17 residents	Simulation use	Usefulness and simulation accuracy.	Participants felt the simulator was realistic and useful for learning surgical techniques. Difficulties were noted with depth perception and the aneurysm clip.
Almousa et al. (2019)	To develop and test an educational VR system with haptic feedback for learning CPR skills.	20 participants (two formal user tests with 10 participants each)	VR use.	Engagement, immersion, ergonomics, performance, and skills' confidence.	The VR simulation increased engagement and provided accessibility. All participants liked the haptic and real-time feedback features.
Cesa et al. (2013)	To compare three strategies (ECT, CBT, IP) for treating obesity with binge eating disorders using VR enhancement.	66 female rehab patients	Type of therapy (VR-enhanced ECT, traditional CBT, or inpatient multimodal treatment).	Weight, binge eating episodes, body satisfaction, and body image.	All groups lost body weight, but the VR condition (ECT) showed the most improvement in body image concerns and long-

					term weight maintenance.
Chang (2021)	To determine if VR application scores affected skill-based learning outcomes for optical-fiber fusion splicing.	60 new employees	Teaching method (Lecture/Demo vs. VR instruction).	Examination results (written technical exam and skill assessment).	VR had a significant positive effect on psychomotor skill learning and smoother transitions between phases, though it increased cognitive load.
De Faria et al. (2016)	To discover the most effective pedagogical method for teaching neuroanatomy using dissected brains.	84 students split into three groups (traditional, interactive computer, interactive with stereoscopic video).	Instructional style (Conventional, Nonstereoscopic interactive, Stereoscopic interactive).	Test performance (post-test evaluation and lab practicum).	Interactive computer-based methods performed better than traditional lectures. Stereoscopy did not add significant benefits over non-stereoscopic interactive lessons.
Detyna & Kadiri (2020)	To determine if VR affected learner engagement in undergraduate and postgraduate geography and digital humanities groups.	70 participants at	VR use within different contexts (geography vs. digital humanities).	Engagement, usefulness, learning objectives, and perceived ease of use.	Majority agreed VR enhanced engagement and was useful. Dizziness was reported during use.
Fabris et al. (2019)	To perform a literature review determining how VR succeeds or fails as an educational tool in bioscience and medical education.	7 studies.	VR use.	Knowledge retention, engagement, presence, and satisfaction.	VR can improve engagement and short-term retention but may cause cognitive overload or health issues if not personalized.
Fernández-Arias et al. (2023)	To analyze professors' assessments regarding the didactic use of VR, comparing Engineering and Health Sciences.	606 professors.	Subject area (Engineering vs. Health) and university tenure (Public vs. Private).	VR self-concept, usability, didactic skills, and technical skills.	Engineering professors scored higher on technical components. Private university professors gave higher ratings for usability and didactic use.
Frederiksen et al. (2020)	To compare cognitive load and performance between conventional VR and immersive VR simulation training for laparoscopic surgery.	31 participants	Training method (Conventional VR vs. Immersive VR).	Cognitive load (reaction time) and performance stats.	Immersive VR was more mentally demanding and resulted in worse performance compared to conventional VR. It is recommended to start with

					traditional VR first.
García Fierros et al. (2021)	To evaluate a VR mobile application (VirtualCPR) for training in cardiopulmonary resuscitation techniques.	32 adult cases	Prior CPR training, use of color indicators, and listening suggestions.	Percentage of accurate chest compressions.	VR training is cost-effective and flexible. Those with previous training had higher accuracy. Potential technology access issues were noted as a disadvantage.
Gunn et al. (2021)	To determine the VR experiences and confidence levels of undergraduate medical imaging and radiation therapy students.	66 students (28 Medical Imaging, 38 Radiation Therapy).	Cohort groups (MI vs. RT) and demographic variables.	Usefulness, ease of use, enjoyment, and confidence.	MI students showed a link between engagement and confidence. Most RT students favored VR. Students preferred guided learning over self-directed.
Haluck & Krummel (2000)	Conceptual review of VR's potential to move surgical training beyond the traditional operating room.	2 studies	Training method (Actual surgery vs. Simulator combination).	Time spent in training.	Simulated training reduces the time needed for actual clinical practice. It is safer, cheaper, and allows for mistakes without risking patient safety.
Heid & Kretschmer (2009)	To create and evaluate a Second Life (SL) environment for promoting lifelong learning in higher education.	Educators and students in higher education (unspecified)	Use of 3-D MUVEs in Second Life.	Learning outcomes and educational acceptance.	Found potential in collaboration, but teacher buy-in was low due to perceived disadvantages and lack of standardization.
Hoffman et al. (2011)	To summarize research on using VR as a pain distraction system for burn patients.	At least 9 participants	VR use (alone or in combination with other therapies).	Pain intensity and pain-related brain activity.	VR use significantly decreased pain and associated negative emotions. Researchers recommend more personalized and comfortable equipment.
Howard & Van Zandt (2021)	Meta-analysis to determine relationships between individual differences and VR sickness.	137 sources (participants mostly college students or adults).	Gender, age, motion sickness susceptibility, experience, and phobias.	VR sickness.	Motion sickness susceptibility, being female, and having phobias or neurological disorders are positively related to VR sickness.

Johnson et al. (2009)	To examine the use of virtual worlds (Second Life) in health care higher education.	Nursing informatics students at Duke University.	Instructional method (Second Life, LMS, or webinars).	Learning, social presence, and interactivity.	Second Life was rated more favorably than traditional LMS for quality of instruction, creating a stronger sense of community.
Kourtesis et al. (2021)	To validate the Virtual Reality Everyday Assessment Lab (VR-EAL) against paper-and-pencil neuropsychological tests.	41 participants from University of Edinburgh.	Assessment type (VR-EAL vs. Paper-and-pencil).	Performance, gaming experience, and pleasantness.	VR-EAL was found to be more ecologically valid and enjoyable. Gamers processed perceptual information faster and completed assessments quicker.
Kumar et al. (2023)	To determine the impact of VR simulators on medical education regarding heart block disease.	607 students (post-grads and undergrads).	Instructional method (Textbook vs. Immersive VR).	Attention, relevance, confidence, satisfaction, and medical knowledge.	VR use positively correlated with medical knowledge and motivation, helping students cope with education requirements during lockdowns.
Lee et al. (2021)	To explore the effects of VR therapy on brain activity in patients with Social Anxiety Disorder (SAD).	28 SAD patients.	VR therapy sessions.	Prefrontal cortex activity (measured by fNIRS).	VR treatment increased activity in the right frontopolar prefrontal cortex, indicating reduced SAD symptoms.
Lemole et al. (2007)	To develop a realistic ventriculostomy simulation with haptic feedback for neurosurgical education.	Faculty, residents, and students at University of Illinois at Chicago.	Simulator method (ImmersiveTouch).	Learning outcomes (surgical task success).	The simulator provided a safe environment for practice and minimized risks. Modular design is recommended for complex procedures.
Lobbestael & Cima (2021)	To determine if VR is an effective tool for assessing reactive and proactive aggression in males.	74 males (24 alley scenario, 50 bar scenario).	Aggressive situations within VR.	Aggression (affect changes and blood pressure).	The tool showed validity for measuring reactive aggression (linked to blood pressure increase) but not for proactive aggression.
Malińska et al. (2015)	To assess the effect of VR immersion on autonomic heart regulation.	19 young males in Poland.	VR use (3D movie vs. virtual workstation task).	Heart rate variability (HRV) and heart rate parameters.	Heart rate values were higher during the virtual workstation task.

					Significant increases in sympathetic performance were observed.
Martirosov et al. (2022)	To determine how different levels of VR immersion are linked to cybersickness.	89 participants (students and staff).	Immersion level (PC, CAVE, Oculus).	Cybersickness and fine dexterity.	Increased immersion (Oculus/CAVE) was linked to higher nausea. Dexterity was not affected by sickness, but oculomotor function decreased.
McFaul & FitzGerald (2019)	To evaluate undergraduate law students' use of a VR smartphone app (Open Justice) in distance education.	95 students.	Use of the Open Justice app.	Student engagement and learning outcomes.	Most students did not engage with the app due to management and distance education challenges, limited by anxiety and functionality issues.
Modrego-Alarcón et al. (2021)	To determine the efficacy of mindfulness-based interventions (MBI) with and without VR support to reduce stress.	Undergraduate and master's students in Spain.	Mindfulness strategy (Relaxation, MBI without VR, MBI with VR).	Perceived stress, well-being, and mindfulness.	MBIs improved stress outcomes. The VR group showed higher retention and attendance rates.
Morimoto et al. (2022)	A narrative review of XR technology (AR, VR, MR) in spine medicine.	Analysis of multiple studies.	XR training (AR guide or VR simulation).	Accuracy, operation time, radiation exposure, and workload.	XR improves accuracy and reduces radiation exposure. However, it can increase fatigue and workload during prolonged use.
Moro et al. (2017)	To compare Oculus Rift (desktop) and Gear VR (mobile) for teaching spine anatomy.	20 students at Bond University.	VR device type (Oculus Rift vs. Gear VR).	Anatomy test scores, engagement, and adverse health effects.	No significant difference in learning outcomes. Gear VR group experienced higher disorientation. Oculus was rated higher for user-friendliness.
Napa et al. (2019)	To evaluate the usability of two VR apps (Bosc and Medical Holodeck)	8 surgeons.	VR application type.	Attitudes, usability (SUS), and task load (NASA-TLX).	Surgeons preferred Medical Holodeck for its clarity and ease of use. They

	for cardiac surgery planning.				highlighted the need for standardized anatomical labeling.
Sancho et al. (2009)	To evaluate if a VR role-playing game (NUCLEO) is effective for motivation and technical knowledge in programming.	Multiple cohorts (60 and 175 students) at University Complutense of Madrid.	Instructional approach (Traditional vs. NUCLEO).	Exam scores and satisfaction survey.	Meaning-directed learners performed better in leadership roles. Students enjoyed the roles but were dissatisfied with group assignments.
Lemole et al. (2007)	To compare Augmented Reality (ProMIS) and Virtual Reality (LapSim) for laparoscopic simulation.	90 subjects (Experts, Intermediates, and Novices).	Simulation type (AR vs. VR).	Realism, haptic feedback, and didactic value.	AR (ProMIS) was rated more realistic for basic skills and suturing, offering better feedback than the VR simulator.
Sapkaroski et al. (2018)	To compare CETSOL VR Clinic with previous Shaderware technology for medical imaging students.	92 students	Simulation software (Shaderware vs. CETSOL VR).	Perception of clinical skill improvement.	Students favored CETSOL for improving patient positioning and communication skills, offering better technology integration.
Singleton et al. (2022)	To test the effect of non-immersive VR simulation on Type 2 Diabetes education for nursing students.	171 nursing students	Teaching method (VR desktop activity vs. Paper-based case study).	Short-term knowledge, attitude, and engagement.	VR group scored significantly higher on posttests regarding hypoglycemia. Confidence and engagement were also higher in the VR group.
Tacgin (2020)	To determine if the myVOR immersive VR environment helped nursing students learn preoperative procedures.	14 nursing students	VR use (myVOR program).	Behaviors, attitudes, reactions, and exam outcomes.	myVOR was more effective than teaching without VR. Hints and aids were necessary for the program's effectiveness.
Tolsgaard et al. (2015)	To determine if dyad (peer) training on a VR ultrasound simulator is as effective as individual training for skill transfer.	30 medical students	Practice strategy (Dyad vs. Monad/Independent).	Simulation scores and clinical transfer test (OSAUS).	Dyads significantly outperformed independent students on transfer tests and were more efficient in training.

Tractenberg et al. (2007)	To evaluate appropriate methods for analyzing attitude changes in medical students following a Mind-Body Medicine course.	70 preclinical medical students at Georgetown University	Exposure to the Mind-Body Medicine (MBM) course.	Attitude (Positive, Neutral, Negative).	Five items showed consistent positive change, including self-awareness and stress management. Statistical significance did not always imply practical significance.
Vapenstad et al. (2013)	To establish construct validity for the LapSim VR simulator and evaluate the effect of haptic feedback on performance.	47 surgical residents (Novices, Intermediates, Experts).	Proficiency level (Novice, Intermediate, Expert).	LapSim task performance.	The simulator lacked construct validity for 18 of 19 parameters. Haptic feedback did not result in significant performance differences.
Vea (2019)	Ethnographic study to determine learning processes of animal rights activists using media technologies.	20 current and former activists.	Media and technology use (VR, 360-degree video, Facebook).	Activities and affective sensations (empathy/literacy).	VR fostered presence and connection, proving ideal for mobilizing existing activists rather than changing non-vegans.
Zhou et al. (2012)	To determine the effect of haptic feedback on laparoscopic surgery skill acquisition (suturing).	20 novice participants.	Haptics use (ProMIS with haptics vs. MIST-VR without).	Time of task completion and learning curves.	Haptics users performed more consistently and plateaued faster. Benefits are most significant in the initial stages of learning.

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