Exploring the use of immersive virtual reality for health sciences education: A scoping review

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Background. Immersive virtual reality (IVR) is an emerging educational technology in health sciences education, providing interactive learning environments that enhance knowledge acquisition, procedural skills and student engagement. IVR may address challenges such as limited clinical placements, staff shortages and restricted access to training; however, concerns remain regarding cost, accessibility and long-term educational outcomes.
Objective. To map the evidence on the use of IVR use in undergraduate health sciences education, focusing on applications, effectiveness, student perceptions and implementation challenges.
Methods. The review followed Arksey and O'Malley's framework and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist. Searches were conducted across PubMed, MEDLINE, BioMed Central, ScienceDirect, Scopus, Web of Science and ClinicalKey for peer-reviewed empirical studies published between 2014 and 2025 involving undergraduate students. Data were extracted and synthesised descriptively.
Results. A total of 39 studies from 23 countries were included, primarily in nursing, radiography and medicine. IVR applications included procedural training, anatomy learning, clinical reasoning, patient care and interprofessional education. Students reported high satisfaction, motivation and confidence, while randomised controlled trials demonstrated outcomes comparable to or superior to those of traditional teaching. Challenges included cybersickness, limited haptic feedback, high costs and inconsistent outcome measures. Evidence from low- and middle-income countries was limited, and few studies evaluated long-term retention or transfer to clinical practice.
Conclusion. IVR shows strong potential as a complementary tool in health sciences education. Future research should prioritise standardised evaluation methods, cost-effectiveness and the inclusion of resource-constrained contexts.

Keywords. Immersive virtual reality, health sciences education, simulation-based learning, undergraduate training, educational technology

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The integration of technology into medical education is accelerating rapidly, with the global market for medical education expected to grow significantly, driven by the widespread adoption of virtual reality (VR).[1] VR systems have gained prominence in healthcare education owing to the improved accessibility and affordability of head-mounted displays (HMDs).[1] The immersive nature of VR is highly appealing, as it may promote motivation and engagement, enhance cognitive processing of learning material and support memory retention and the application of new knowledge.[1-4]

VR technology may help address challenges inherent in traditional undergraduate health sciences training. Students may experience reduced concentration and involvement when conventional lecture-based teaching methods are used.[2,5] In addition, traditional experiential learning, such as role-playing or live simulations, often face limitations in recreating realistic scenarios and safe clinical environments owing to constraints related to cost, space and patient safety.[3,5-7] Immersive virtual reality (IVR) creates a simulated environment that encompasses the user perceptually and provides a strong sense of presence, enabling students to engage customised, repeatable practice without risk to real patients.[3,5,8,9]

The application of IVR spans a growing range of clinical training modalities and disciplines within undergraduate health sciences education, yielding promising educational outcomes. In fields such as nursing, VR simulation programmes have been used to teach essential psychomotor skills and practical procedures, including infection control protocols, high-risk neonatal care and intravenous catheter insertion.[3,6,10] Studies have examined the use of VR to teach medical students complex, high-stakes emergency medicine skills, such as triage and basic life support protocols.[5,11] The results suggested that VR may improve knowledge and competency, with studies reporting effectiveness comparable to that of traditional training methods. In addition, the overall operational time decreased once students had been trained to use the VR system effectively.[5,11,12]

Beyond the teaching of technical skills, IVR may also support the development of essential professional attitudes and communication competencies. Cinematic VR, which uses a live 360-degree video, has been shown to improve cultural self-efficacy, attitudes toward patients with diabetes and empathy among health sciences students by enabling them to experience scenarios from a patient's perspective.[1,3] Furthermore, VR training has been successfully applied to patient communication strategies, such as the ISBAR (identify, situation, background, assessment and recommendation) handover approach, achieving high usability ratings and increased student motivation.[13,14]

Other fields, including radiography and dentistry, have also benefited from realistic VR simulations. For example, IVR systems with haptic and visual feedback have been used in operative dentistry to train cavity preparation, thereby improving manual dexterity and psychomotor skills.[14] Similarly, VR training for patient positioning in radiation therapy has been shown to improve students' understanding and confidence significantly.[12,15]

Despite the demonstrable potential and positive student perceptions of IVR's realism and engagement, limitations exist, including the high cost of development and maintenance, reliance on technical support and reports of physical discomfort, such as motion sickness and eye strain.[3,10,11,14,16] Although preliminary findings are encouraging, authors emphasise the need for larger-scale research, including randomised controlled trials (RCTs), to evaluate the long-term effectiveness of IVR interventions on clinical training outcomes across diverse undergraduate health sciences disciplines.[1,3,11] This scoping review aimed to synthesise the current evidence on the use of IVR in undergraduate health sciences education by mapping the extent and nature of the available research and identifying key applications and knowledge gaps.

Objective

To map the existing body of literature on the use of IVR in health sciences education. The review was guided by the research question: What is the extent, range and nature of available evidence on the use of IVR in undergraduate health sciences education? Specifically, it explored how IVR is implemented, evaluated its effectiveness and user perceptions and identified key challenges, gaps and future research directions. The overarching goal was to contribute to the evidence base supporting the integration of IVR into undergraduate health sciences education in South Africa (SA).

Methods

This scoping review was conducted in accordance with Arksey and O'Malley's framework,[17] with data extraction and charting guided by the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis.[18] The review process and reporting adhered to the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) checklist, as outlined by Peters *et al.*[18] In line with PRISMA-ScR guidance, no formal quality appraisal of the included sources was undertaken. Ethical approval (ref. no. SMUREC/H/379/2024:UG) was obtained from a university in SA.

Search strategy

The first author (NK) conducted a comprehensive search across seven electronic databases available at the institution: PubMed, MEDLINE, BioMed Central, ScienceDirect, Scopus, Web of Science and ClinicalKey. An information specialist repeated the search strategy to enhance methodological credibility. The search strategy involved a combination of keywords reflecting the core concepts, 'immersive virtual reality' OR 'virtual reality simulation' OR 'VR simulation' OR 'fully immersive VR' OR 'head-mounted display' OR 'HMD' OR '3D simulation' OR 'virtual patient simulation' OR 'VR-based training' AND 'health sciences education' OR 'medical education' OR 'nursing education' OR 'audiology education' OR 'speech-language pathology education' OR 'physiotherapy education' OR 'occupational therapy education' OR 'dietetics education' OR 'dentistry education' OR 'optometry education' OR 'clinical training' AND 'clinical training' OR 'procedural training' OR 'clinical skills' OR 'manual skills' OR 'technical skills' OR 'hands-on training' OR 'skill acquisition' OR 'competency-based training'. The reference lists of all included articles were also manually screened for relevant studies. The final search was completed in January 2026.

Eligibility criteria

The eligibility criteria for this review were guided by the Population, Intervention, Comparison and Outcome (PICO) framework, as outlined in the JBI Reviewer Manual.[18] To be included, studies had to be empirical, published between 2014 and 2025 in English-language, peer-reviewed journals and focused on the use of IVR in undergraduate health sciences clinical training. Exclusion criteria included non-peer-reviewed sources, review articles, discussion papers, dissertations, conference proceedings, opinion pieces, viewpoints and preprints. Studies involving postgraduate students or qualified healthcare professionals were also excluded.

Study selection

Studies retrieved from the seven databases were imported into Rayyan software (Qatar Computing Research Institute, Qatar), where the first author (NK) identified and removed duplicates. The remaining records were then screened at the abstract and full-text levels using Rayyan. Both authors (NK and KE) independently screened the titles, keywords, abstracts and full texts while blinded to each other's decisions. Discrepancies were discussed and resolved through consensus without the need for a third reviewer.

Data extraction and analysis

An Excel spreadsheet (Microsoft, USA) was used to tabulate information from the included studies, including country of study, study design, aim, target population, sample size, duration of IVR training, type of IVR used, IVR platform or software used, description of IVR simulation, presence of haptic feedback, learning objectives, comparison group, outcomes, key findings, gaps and future recommendations (Supplementary material I).

Data were analysed using a descriptive narrative synthesis approach. Patterns, themes and trends across the studies were identified and synthesised to provide an overview of the current state of the evidence. Both authors reviewed the emerging synthesis, and any discrepancies were discussed and resolved. Data were analysed using descriptive statistics in Microsoft Excel to summarise study characteristics and thematic analysis to examine content characteristics.

Results

The final search yielded 39 articles. Fig. 1 presents the PRISMA flow diagram outlining the search and selection process.

Study characteristics

A total of 39 studies published between 2014 and 2025 were included. The studies were conducted across 23 countries, with most originating from Europe (*n*=19),[19-37] Asia (*n*=10),[38-47] Australia (*n*=3),[48-50] North America (*n*=5),[51-55] South America (*n*=1)[56] and Africa (*n*=1).[57] The majority involved undergraduate students in health sciences disciplines, including nursing midwifery (41.0%),[6-8,24,25,29,35,38-42,46,47,51,52] radiography and medical imaging (20.5%),[19,26-28,30,49,50,56] medicine (23.1%),[20,22,23,33,37,44,48,53,54] physiotherapy (7.7%),[34,43,45] dentistry (2.6%),[31] audiology (2.6%)[21] and other or mixed health professions (2.6%).[30] The included studies involved undergraduate students across multiple disciplines, with sample sizes ranging from 12 to 239 participants (median of 58 participants). Table 1 summarises the applications per discipline.

The methodological designs were diverse. RCTs or pilot RCTs accounted for 30.8% of the studies,[20-24,29,31,33,38] while others used quasi-experimental designs (15.4%),[36,41,42,51,52,55] cross-sectional surveys (12.8%),[26,30,39,53,56]

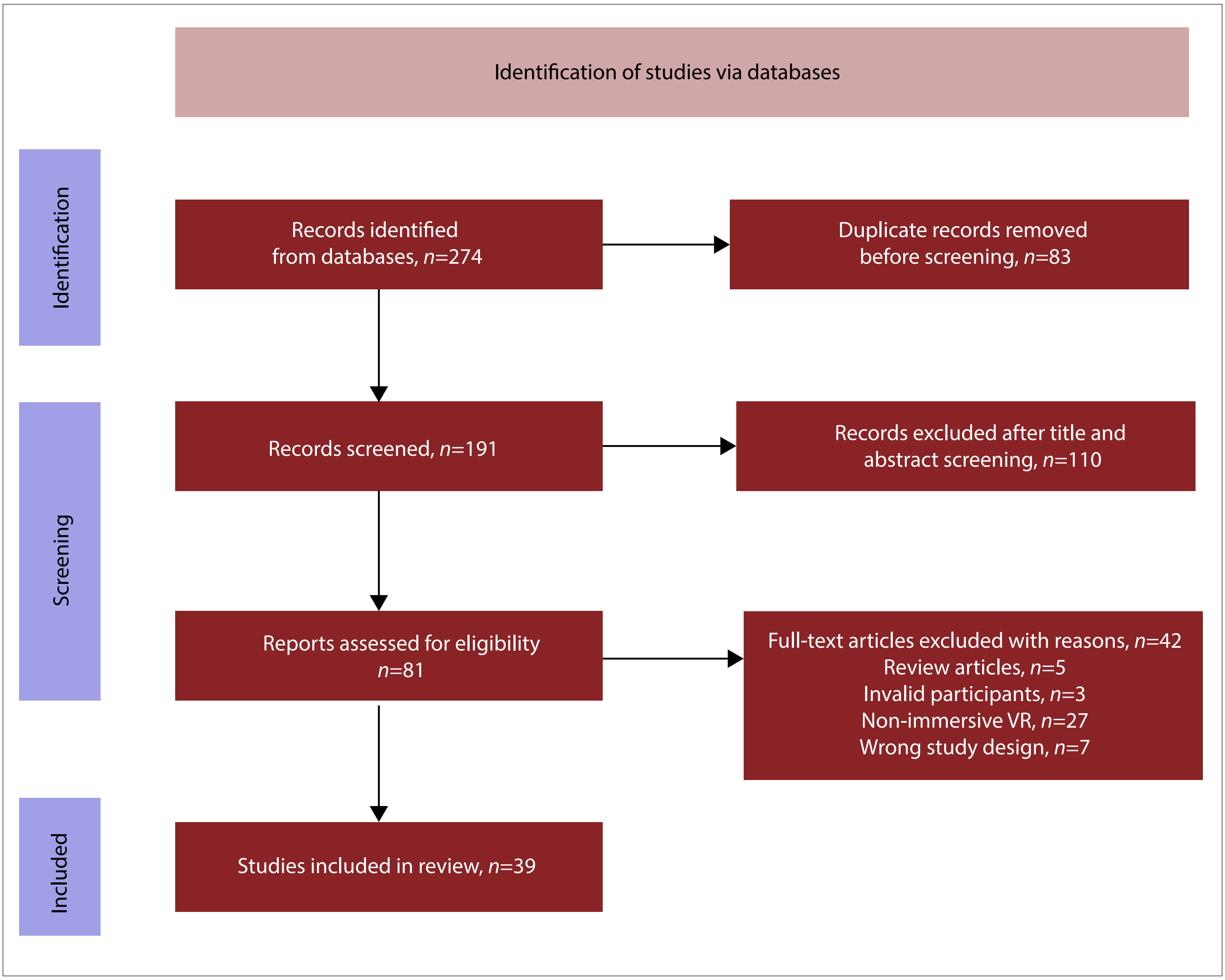

Fig. 1. PRISMA-ScR flow diagram.

Table 1. IVR applications per discipline

Discipline	Number of studies (N=39)	Most common platform used	Most outcomes measured	Key findings and positive outcomes
Nursing and midwifery	16	Head-mounted immersive VR	Knowledge, clinical skills and confidence	Improved learning, confidence and engagement
Radiography and medical imaging	8	3D immersive radiology simulations	Technical skills, accuracy and confidence	Improved technical accuracy, image interpretation and reduced anxiety
Medicine	9	HMD VR for anatomy and procedures	Knowledge, procedural competence and engagement	Enhanced anatomy understanding and procedural readiness
Physiotherapy	3	Task-oriented immersive VR	Skills application, patient management and confidence	Supported skill development and decision-making
Dentistry	1	VR dental simulators	Manual dexterity, skills and knowledge	Improved technical competence and confidence
Audiology	1	Immersive auditory VR	Clinical skills and patient engagement	Promising opportunities for skill development
Other (mixed professions)	1	Interprofessional immersive VR	Collaboration, teamwork and reasoning	Promoted interprofessional learning and teamwork

VR = virtual reality; 3D = three-dimensional; HMD = head-mounted display.

mixed-methods approaches (2.6%),[39] retrospective reviews (2.6%),[19] pre-post experimental designs (7.7%),[29,35,37] observational or descriptive designs (7.7%),[32,43,57] specialised experimental or pilot designs (12.8%)[34,47-50] or qualitative designs (7.7%).[29,39,40]

Across most studies, IVR-based interventions demonstrated significant improvements in knowledge acquisition (41.0%), procedural skills (56.4%) and student confidence (41.0%).[19-28,30,31,33,34,37-42,45-50,55,56] Improved performance was reported in tasks such as catheterisation, surgical procedures and triage. For example, medical students trained using IVR showed superior skill transfer to cadavers. In RCTs, IVR often performed comparably to (30.8%) or better than conventional training.[20-24,30,40,41,45-47,49] However, a few studies reported comparable outcomes (23.1%) among the total studies.[20,21,23,24,30,40,41,46,49]

Content characteristics

Implementation of IVR in health sciences education

IVR was applied across a range of educational contexts, including procedural skills training, assessment, clinical reasoning and non-technical skills such as communication. Applications included clinical skills training (e.g. ultrasound-guided procedures, tracheal suctioning, audiometry and radiographic positioning), simulation of patient interactions (e.g., ental health and suicide risk assessment) and anatomy or rehabilitation training.[2,20-25,29-31,33-36,38,39,41,42,45-53,55]

Commonly assessed outcomes included skill performance, psychomotor skills, student perceptions and satisfaction system usability and procedural knowledge.[2,19-27,31-42,44-51,53-56]

Delivery modalities included HMDs (e.g. Oculus Rift), Meta Quest devices, 360-degree IVR video, HTC Vive systems and custom-built VR simulators.[19-33,35-42,44-51,53,54,56]

Training duration varied considerably, ranging from single sessions lasting less than an hour to repeated sessions and longitudinal use across academic semesters.[19,21,22,24,25,28-30,35-39,41,44,45,47,48,53-56]

User perceptions

Feedback was consistently positive across most studies, with students reporting high levels of engagement, motivation and satisfaction with IVR-based learning experiences. Students particularly valued the immersive and interactive nature of IVR technology, as well as its ability to replicate real-world clinical environments within a safe, controlled learning setting where mistakes could be made without consequences.[19,21,22,24,25,27,29-31,35-41,44-48,50,53-56]

Despite these positive perceptions, several implementation challenges emerged. Technical issues were the most frequently reported barrier, ranging from hardware malfunctions to software glitches that disrupted learning sessions. Cybersickness affected some users, manifesting as nausea or discomfort during IVR exposure. Initial difficulties with device usability also posed challenges, as students required time to become familiar with IVR interfaces and navigation systems.[19,22-24,28,29,33,38-40,47-49,56]

In most studies, these challenges diminished following brief familiarisation periods, with studies indicating that platforms became easier to use over time.[21,23,25,30,31,39,41,49,50,55,56] To support this transition, several studies recommended instructor supervision and guidance, especially during the early stages of implementation.[19,39-41,47-49,56] A smaller subset of studies conducted formal usability evaluations, using standardised measures such as the System Usability Scale to assess user experience and identify areas for improvement.[25,31,33,39,56]

Challenges, gaps and future directions

Several critical gaps were identified. Long-term knowledge retention received minimal attention, with most research focusing on immediate outcomes rather than sustained learning.[23,47,49] The transfer of IVR-acquired skills to clinical practice was similarly underexplored, leaving uncertainty regarding whether improvements observed during virtual training are reflected in real-world clinical performance.[21,23,31,47,49]

Geographic representation was uneven, with relatively few studies originating from low- and middle-income countries (LMICs) compared with high-income settings.[7,19-35,17-41,44-56] This disparity limits understanding of IVR implementation across diverse, resource-constrained contexts. Cost and accessibility barriers were frequently cited, alongside scalability challenges related to equipment availability and instructor training requirements.[19,21,23,24,29,31,33,34,38-40,48-50]

Methodologically, single-centre studies dominated, restricting the generalisability of the findings.[20,21,23-42,44-50,53,55] In addition, the absence of standardised outcome measures hindered meaningful comparisons across studies. Future research priorities consistently emphasised multicentre trials and cost-effectiveness evaluations to support sustainable curricular integration.[19,21,23-26,29-34,39-41,47-50] Longitudinal studies were recommended by more than half of the research teams to assess long-term outcomes, while eleven studies called for standardised assessment tools to facilitate robust cross-study comparisons and further evaluate the role of IVR in health sciences education.[19-26,28-34,39-41,47-49]

Discussion

Key findings

By synthesising patterns across 39 studies published between 2014 and 2025, this scoping review addressed the question: What is the extent, range and nature of available evidence on the use of IVR in undergraduate health sciences education? The findings indicate increasing adoption of IVR across multiple health disciplines, particularly nursing, radiography and medicine, with most evidence originating from high-income countries. This distribution highlights growing global interest while also revealing an important geographic imbalance in the evidence base.

Across the included studies, IVR was most frequently implemented to support procedural training, clinical decision-making and experiential learning. The evidence consistently demonstrates improvements in procedural competence, efficiency and knowledge acquisition, with outcomes that were comparable to or superior to those associated with traditional teaching approaches.[10,12,19] These patterns align with the multimedia learning theories of Kazu and Yalçın and Mayer, which propose that multisensory instructional design may enhance cognitive processing and learning outcomes.[58,59]

A second theme concerned the development of non-technical competencies. Studies reported increases in student confidence, self-efficacy, engagement and empathy following IVR-based learning experiences.[1,3,6,38,54] Immersive simulation environments facilitated experiential understanding and emotional engagement, supporting descriptions of IVR as an 'ultimate empathy machine', although attitudinal changes were not observed consistently across all domains.[1]

Student perceptions were generally positive, with high levels of satisfaction and usefulness reported across settings.[10] Implementation challenges included cybersickness, technical limitations and substantial financial costs.[11,14,24,29,40,51] These recurring barriers suggest that, while IVR offers considerable educational potential, scalability and sustainability remain key considerations.

Collectively, the evidence suggests that IVR functions primarily as a complementary educational strategy, offering benefits for experiential and skills-based learning while highlighting important gaps related to equitable access and implementation feasibility.

Implications for health science education

The findings of this review underscore the relevance of IVR as an innovative complement to traditional teaching and learning methods in health sciences education. By providing immersive, standardised environments, IVR may help address gaps in clinical training, particularly in contexts where access to patients is limited, such as during pandemics or in resource-constrained settings. Its capacity to improve confidence, procedural competence and engagement suggests that carefully integrated IVR experiences may support preclinical readiness and competency-based education.

For educators, IVR provides opportunities to design experiential learning activities that extend beyond conventional simulations, fostering critical thinking, decision-making and interprofessional collaboration. However, its integration should be guided by clear pedagogical objectives rather than technology-driven adoption. Alignment with accreditation requirements and curricular outcomes will be key to ensure its educational value. Institutions should also consider practical factors such as cost, infrastructure, staff training and technical support. Without sustainable implementation strategies, IVR may remain a niche innovation, inaccessible to institutions with limited resources. Collaborative approaches, including shared IVR resources, partnerships with technology developers and inter-institutional networks, may offer cost-effective pathways to adoption, especially in LMICs.

Finally, this review highlights the importance of faculty development. Educators should acquire the skills required to integrate IVR effectively into curricula and evaluate its educational outcomes. Student feedback further emphasised the importance of addressing cybersickness, simulation usability and simulation authenticity to maximise engagement and learning. These implications suggest that, while IVR is unlikely to replace traditional clinical training, it may significantly enrich health sciences education when embedded in a blended, evidence-informed approach.

Future research

Future research should move beyond short-term outcomes to evaluate knowledge retention, the transfer of skills to clinical practice and the long-term educational effectiveness of IVR. Greater inclusion of LMICs is critical to address equity concerns and improve the global applicability of the evidence base. Standardised outcome measures and evaluation frameworks would improve comparability across studies and strengthen the evidence base. Multicentre collaborations could enhance generalisability, while cost-effectiveness analyses would help identify sustainable implementation models. Research exploring strategies to reduce hardware and software expenses, as well as innovations that improve realism, haptic feedback and patient interaction, will be important for advancing IVR as a scalable and equitable educational tool.

Strengths and limitations

A strength of this review is its comprehensive search strategy across multiple databases. The inclusion of diverse study designs (RCTs, quasi-experimental studies, surveys and qualitative research) enabled a broad overview of effectiveness and student perceptions. Mapping evidence across multiple health sciences also provides valuable insights into discipline-specific applications and common themes.

Several limitations should be acknowledged. First, as a scoping review, this study did not include a formal quality appraisal of the evidence and the findings should therefore be interpreted with caution. Second, language restrictions and the exclusion of unpublished or non-indexed studies may have resulted in the omission of relevant literature. Third, heterogeneity in study designs, outcome measures and IVR platforms limited direct comparisons across studies. Finally, the review reflects research published up to June 2025, and more recent studies may not have been captured.

Conclusions

This study highlights the growing use of IVR in health sciences education. By providing immersive, engaging, interactive learning environments, IVR supports visual comprehension, procedural training and opportunities to practise complex skills in safe, standardised settings without risk to patients. Across the included studies, students generally reported high levels of satisfaction, motivation and realism, which were associated with improved confidence, critical thinking, clinical reasoning and communication skills. While IVR is particularly valuable in situations where access to clinical training was limited, such as during the COVID-19 pandemic, the evidence suggests that it is best positioned as a complement to rather than a replacement for traditional clinical training.

Despite its promise, several challenges remain, including cybersickness, limited haptic feedback, technical and financial barriers and difficulties in simulating authentic patient interactions. Furthermore, current research is dominated by studies from high-income countries, underscoring the need for greater representation of African and other underrepresented contexts. Addressing gaps related to long-term outcomes, scalability, equity and cost-effectiveness will be important for informing future implementation. Larger and more diverse studies, collaborative development of tailored IVR tools and integration into institutional curricula may further support the effective use of IVR in health sciences education. With sustained research and innovation, IVR may serve as a powerful educational resource for preparing future health sciences professionals for the complexities of clinical practice.

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Author contributions. NK conceptualised and designed the study, identified sources and screened them according to the inclusion and exclusion criteria. KE assisted with confirming article eligibility and data analysis. Both authors interpreted the results. KE drafted the manuscript, and both authors approved the final version.

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