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2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

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VIRTUAL REALITY IN MEDICAL EDUCATION: THE IMPACT ON PROFESSIONAL SOCIALIZATION AND EMPATHY - A NARRATIVE REVIEW

Sebastian Ożga (Corresponding Author, Email: sebastian.ozga17@gmail.com)
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0003-1337-7800

Piotr Tryczyński
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0001-8997-3225

Jakub Sałak
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0005-7078-6402

Piotr Helbin
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0007-5289-2521

Jakub Wrona
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0005-7722-7507

Wiktoria Laskowska
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0000-8116-0038

Wiktoria Donocik
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0003-3801-6729

Klaudia Kwolek
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0003-2145-7528

Marcel Pilarek
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0004-4114-5078

Aleksandra Spirkowicz
Medical University of Silesia in Katowice, Katowice, Poland
ORCID ID: 0009-0006-2228-4536

ABSTRACT

Background: Medical education is experiencing a digital transformation, moving from the traditional "See One, Do One, Teach One" apprenticeship model toward immersive Simulation-Based Medical Education (SBME). This narrative review explores how Virtual Reality (VR) acts as a transformative catalyst to reshape the professional socialization and clinical attitudes of future physicians.

Methods: The study utilizes a narrative review methodology, synthesizing interdisciplinary research identified through a multi-stage search of global bibliographic databases. The analytical framework employs a thematic synthesis approach, utilizing the four-level Kirkpatrick model to evaluate educational reactions, learning, behavior, and results. Specialized themes categorize interventions based on their impact on professional identity formation and both cognitive and affective empathy.

Results: Findings demonstrate that VR serves as a scalable bridge between theory and practice, enhancing psychomotor skills, spatial orientation, and patient safety. Immersive virtual embodiment allows students to experience patient perspectives, fostering ethical internalization and empathy. However, the data highlights a persistent "empathy gap" where technical efficiency might lead to desensitization. Furthermore, a "digital divide" manifests through high implementation costs, reinforcing educational hierarchies between high-income and resource-limited institutions.

Conclusion: VR facilitates a profound paradigm shift by standardizing clinical training and promoting global professional socialization. While offering significant pedagogical benefits, the sustainability of relational gains remains a recognized gap requiring longitudinal validation. Future integration with Artificial Intelligence and haptic feedback is essential to balance technological innovation with the humanistic, patient-centered dimensions of medical practice.

KEYWORDS

Virtual Reality, Medical Education, Professional Socialization, Clinical Empathy, Simulation-Based Medical Education, Professional Identity

CITATION

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1. Introduction

The contemporary landscape of healthcare and clinical training is currently navigating a profound digital transformation, characterized by the rapid integration of immersive technologies into established institutional frameworks (Pottle, 2019; Dhar et al., 2023; Goh & Sandars, 2020). This evolution represents a significant paradigm shift from traditional apprenticeship models, historically defined by the "See One, Do One, Teach One" approach, toward more structured, Simulation-Based Medical Education (SBME) (Pottle, 2019). In this context, immersive virtual environments are no longer viewed as mere technological novelties but as transformative catalysts capable of reshaping the professional socialization and behavioral patterns of future clinicians (Pottle, 2019; Røe et al., 2025). As traditional education models based on direct patient contact and resource-intensive physical simulations face increasing pressure from budgetary constraints and the need for standardized quality, digital ecosystems - particularly Virtual Reality (VR) - emerge as a scalable "bridge" connecting theoretical knowledge with real-world clinical practice (Pottle, 2019; Liu, 2024). This transition facilitates a move from passive learning to the active, safe performance of procedures, fundamentally altering the way healthcare professionals internalize their clinical roles and responsibilities (Pottle, 2019; Røe et al., 2025).

The emergence of gamified and immersive interventions in health training is driven by the necessity for safe, repeatable, and fully controlled educational environments (Pottle, 2019; Alghanaim, 2025). Documentation within the field suggests that immersive Virtual Reality (IVR), specifically systems utilizing Head-Mounted Displays (HMDs), provides a level of presence and engagement that traditional, screen-based simulations fail to replicate (Pottle, 2019; Zhang et al., 2025; Mundok et al., 2026). These digital environments act as an extension of classical high-fidelity simulators, offering solutions that transcend geographic and

institutional boundaries (Pottle, 2019). By creating high-fidelity virtual replicas of complex anatomical structures or physiological systems - often referred to in emerging research as the "Digital Twin" concept - these technologies allow for the infinite repetition of high-stakes procedures "on demand" (Liu, 2024; Pottle, 2019). This level of repeatability is crucial for the development of technical proficiency and psychomotor skills, such as manual coordination and spatial orientation, which are reported to be significantly improved in VR-mediated environments compared to traditional 2D methods (Kyaw et al., 2019; Kim & Kim, 2023; Zhao et al., 2021).

The adoption of these technologies in clinical contexts is increasingly interpreted through its behavioral and social dimensions rather than its technical functionality alone (Alghanaim, 2025; Røe et al., 2025). Immersive simulations allow participants to move beyond rote learning to experience a profound sense of presence, often described as a psychological state of "being there" (Pottle, 2019). This heightened engagement directly influences cognitive and behavioral outcomes, fostering a fundamental shift in how learners perceive their roles - moving from passive observers to active participants within clinical narratives (Pottle, 2019; Røe et al., 2025). Evidence suggests that these technology-mediated environments facilitate "neurologic immersion," a mechanism associated with the release of oxytocin during engaging narratives, which may provide a neurobiological foundation for social bonding and behavioral adaptation (Keckler et al., 2025). Such immersive experiences encourage students to experiment with different interpersonal strategies and "fail" in a low-risk environment, effectively preparing them for the unpredictable nature of actual clinical encounters without compromising patient safety (Pottle, 2019; Alghanaim, 2025; Tay et al., 2025).

Furthermore, the social implications of technology-mediated training extend to the development of empathy and "bedside manner" (Pottle, 2019; Xu & Yang, 2025). Immersive simulations enable students to directly "experience" the patient's perspective through the process of virtual embodiment (Elzie & Shaia, 2021). By utilizing "Embodied Labs" modules, students can virtually "become the patient," experiencing the daily struggles and symptoms associated with aging, dementia, or terminal illness (Elzie & Shaia, 2021). These interventions are reported to deepen the understanding of the subjective experience of illness and foster a deeper commitment to patient-centered care (Elzie & Shaia, 2021; Alfakir et al., 2025). For instance, in psychiatric education, VR simulations focusing on psychosis and schizophrenia have been shown to shift student attitudes and significantly reduce the stigma associated with mental illness (Marques et al., 2022; Zare-Bidaki et al., 2022). Similarly, the use of haptic feedback technologies, such as gloves that simulate manual dexterity limitations or hearing loss, allows students to experience the physical impairments typical of geriatric patients (Alfakir et al., 2025). These interventions bridge the gap between theoretical knowledge and the visceral reality of patient care, facilitating the internalization of professional ethics and compassionate communication (Elzie & Shaia, 2021).

However, the integration of VR into medical training also introduces a complex dynamic between the acquisition of technical proficiency and the preservation of relational competencies (Mundok et al., 2026). A recurring theme in the reviewed literature is the concern regarding a persistent "empathy gap" or a potential for desensitization resulting from a heavy reliance on virtual environments (Pottle, 2019; Mundok et al., 2026). Evidence suggests that immersive training can lead to an over-emphasis on technical milestones at the expense of humanistic care, where learners may come to view the virtual patient (VP) as a set of clinical tasks rather than a person requiring empathic engagement (Pottle, 2019). This tension between "efficiency" and "authenticity" highlights the risk of narrowing the learner's focus to technical mastery, potentially neglecting the social cues and emotional nuances inherent in real-world doctor-patient relationships (Alghanaim, 2025; Yamada et al., 2026). While Artificial Intelligence (AI)-driven avatars and Virtual Patients (VPs) offer scalable and repeatable alternatives for practicing clinical dialogue and history-taking, they are currently viewed as preparatory tools that require supplementation in actual clinical settings to capture the full complexity of human interaction (Rodda et al., 2025; Yamada et al., 2026).

The existing research landscape further highlights the role of the "hidden curriculum" within digital learning environments (Pottle, 2019; Alghanaim, 2025). Immersive technologies facilitate Interprofessional Education (IPE), where students from diverse healthcare disciplines interact within a shared virtual world to practice non-technical skills (NTS), teamwork, and ethical collaboration (Alghanaim, 2025). These shared clinical experiences provide standardized mentorship at scale, promoting a global professional culture (Pottle, 2019). Nevertheless, the rapid adoption of these digital solutions - catalyzed by the COVID-19 pandemic - has simultaneously exposed significant socio-economic disparities (Dhar et al., 2023; Goh & Sandars, 2020). A "digital divide" manifests at both institutional and individual levels, where access to advanced knowledge in surgery or anatomy increasingly depends on the financial capacity of the institution (Pottle, 2019; Radianti et al., 2020). High implementation costs, infrastructure requirements, and the need for continuous technical support create barriers that may reinforce existing educational hierarchies between high-income countries and resource-limited regions (Pottle, 2019).

Despite the documented benefits in skill acquisition and immediate affective empathy, there remains a recognized gap in the literature regarding the long-term professional development and the sustainability of relational gains (Xu & Yang, 2025; Mundok et al., 2026). Methodological limitations, such as the dominance of pilot studies with small sample sizes and a reliance on subjective self-report scales, complicate the direct comparison of results across studies (Alghanaim, 2025; Mundok et al., 2026). There is an expressed need for more robust, longitudinal data to establish permanent training standards and to ensure that digital tools provide a "standardized clinical experience" equivalent to traditional simulation methods (Pedram et al., 2023; Xu & Yang, 2025). Furthermore, the field is still moving toward unified certification processes and validation frameworks to govern the integration of VR into medical curricula (Pedram et al., 2023).

The purpose of this narrative review is to synthesize the existing evidence concerning the role of immersive technologies in transforming contemporary clinical training models. While technical proficiency remains a core component of medical education, this review emphasizes the broader behavioral, social, and educational implications of technology-mediated learning (Alghanaim, 2025; Røe et al., 2025). By interpreting findings within an interdisciplinary framework of social science and technological innovation, this paper seeks to explain the mechanisms through which virtual environments shape professional identity and clinical attitudes (Røe et al., 2025). The objective of this narrative review is to provide an integrated analysis of the social and behavioral impacts of gamified rehabilitation and training environments, highlighting how these digital ecosystems influence empathy, professional socialization, and the evolving culture of medical training (Pottle, 2019; Alghanaim, 2025; Elzie & Shaia, 2021).

2. Methodology

The present narrative review was conducted to evaluate the impact of VR on professional socialization and empathy in medical education. The methodology was designed to identify, select, and synthesize existing literature regarding the transition from traditional apprenticeship models to SBME. The analytical framework focused on the educational, behavioral, and social implications of immersive technologies within digital learning ecosystems.

2.1 Literature Identification and Search Strategy

Relevant literature was identified through a multi-stage search process across a comprehensive range of scientific digital libraries and bibliographic databases. The identification process aimed to capture interdisciplinary research at the intersection of technological innovation, medical training, and social science. The primary sources utilized for this review included PubMed, Web of Science, Scopus, Embase, and the Cochrane Library. To ensure a global perspective on technology adoption, additional databases such as IEEE Xplore, Science Direct, Springer Link, and regional repositories - including the Chongqing VIP Database (VIP), Chinese National Knowledge Infrastructure (CNKI), and the Wan Fang Database - were systematically searched.

The search strategy employed specific keywords and Boolean operators to capture the dual focus on technical proficiency and relational competencies. Primary search terms included "virtual reality," "immersive virtual reality," "head-mounted display (HMD)," "medical education," "nursing education," "empathy," "professional socialization," and "interprofessional education." For specialized domains, terms such as "surgical training," "anatomy," "psychiatry," and "clinical communication" were utilized. Search parameters for specific systematic and scoping reviews within the corpus ranged from the inception of databases to specific cutoff dates in early 2024 and 2025, ensuring the inclusion of recent digital transformations necessitated by the COVID-19 pandemic.

2.2 Study Selection Procedures

The study selection process followed standardized methodological frameworks to ensure rigor and reproducibility. Where applicable, the selection was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the PRISMA extension for Scoping Reviews (PRISMA-ScR). In instances involving IPE, the Arksey and O'Malley methodological framework was applied.

The screening process involved the independent evaluation of titles and abstracts, followed by a full-text review of potentially relevant articles. For experimental and quasi-experimental studies, at least two researchers conducted the review, with a third researcher available to resolve disagreements. This structured selection process aimed to identify patterns in how VR is utilized as a "bridge" between theoretical knowledge and clinical practice.

2.3 Inclusion and Exclusion Criteria

The inclusion criteria were established to capture studies that provided evidence on the behavioral and social impacts of VR-based medical training. Studies were included if they met the following parameters:

1. Target Population: Learners in the health professions, including medical students, nursing students, residents, and interprofessional healthcare teams (e.g., physiotherapy, radiology technology).
2. Intervention Type: Educational programs utilizing IVR specifically those involving HMDs or VPs. Interventions focusing on "Embodied Labs" modules for terminal illness or geriatric care and simulations for managing agitated patients in psychiatric settings were prioritized.
3. Outcome Measures: Studies assessing psychomotor skills, cognitive and affective empathy, professional identity formation, clinical judgment, and NTS such as teamwork and reflection.
4. Comparison: Research comparing VR to traditional educational methods, including lectures, 2D videos, high-fidelity physical simulators (HFS), or standardized patients (SPs).

Exclusion criteria were applied to maintain a focus on immersive, technology-mediated environments. Studies were excluded if they:

1. Focused on learners outside of the health professions.
2. Utilized exclusively screen-based or computer-based simulations without an immersive component.
3. Did not involve a comparison to traditional simulation or traditional pedagogical models.
4. Lacked empirical data on educational or social outcomes.

2.4 Data Extraction and Quality Assessment

Information was extracted from the selected studies using standardized data extraction forms. The extracted data included study design (e.g., Randomized Controlled Trials, quasi-experimental, mixed-methods), participant demographics, the specific VR modality used, and the clinical or social domain addressed.

To maintain methodological rigor, the quality of the selected studies was assessed using several high-quality assessment tools identified in the literature. These included:

- MERSQI (Medical Education Research Study Quality Instrument): Used to assess the methodological quality of medical education research.
- JBI (Joanna Briggs Institute) Critical Appraisal Tools: Utilized for assessing the quality of RCTs and quasi-experimental studies.
- MMAT (Mixed Methods Appraisal Tool) and CASP (Critical Appraisal Skills Programme): Applied to evaluate mixed-methods and qualitative research components.
- Modified Buckley Checklist: Employed in specific systematic reviews to ensure consistent quality across experimental studies.

2.5 Analytical Approach and Thematic Synthesis

The extracted information was analyzed through a thematic synthesis approach, designed to explain the mechanisms behind the observed educational and behavioral effects of VR. The synthesis was organized around the transition from the historical "See One, Do One, Teach One" model to a structured SBME framework.

The analysis of educational outcomes followed the four-level Kirkpatrick model to standardize the assessment of:

1. Reaction: Student engagement, sense of presence, and subjective feedback.
2. Learning: Acquisition of medical knowledge, psychomotor skills, and manual dexterity.
3. Behavior: Changes in clinical thinking, de-escalation skills, and communication techniques.
4. Results: Impacts on patient safety, standardization of training, and skill transfer to physical clinical practice.

Specialized themes were identified through a qualitative synthesis of findings related to professional socialization and empathy. This involved categorizing interventions based on their impact on "cognitive empathy" (perspective-taking and understanding) and "affective empathy" (emotional responses such as compassion). The synthesis also addressed the "hidden curriculum" within digital environments, examining how shared virtual spaces foster interprofessional working and the internalization of professional ethics.

Finally, the methodology included an analysis of the socio-economic and institutional factors influencing technology adoption. This involved identifying disparities in access between high-income countries (HICs) and low- and middle-income countries (LMICs), as well as the economic barriers related to initial infrastructure investments and technical support. The impact of the COVID-19 pandemic was analyzed as a catalyst for the rapid digitalization and adoption of these instructional frameworks.

3. Results

3.1 Transforming Clinical Education Models: Virtual Reality as a Catalyst in the Transition from the "See One, Do One, Teach One" Model to Simulation-Based Education (Pottle, 2019)

Contemporary medical education is undergoing a significant paradigm shift, in which SBME is becoming the cornerstone of clinical training (Pottle, 2019). Reports indicate that traditional education models, based on direct patient contact and resource-intensive physical simulations, are increasingly being supplemented or replaced by immersive technologies (Pottle, 2019; Kyaw et al., 2019). Accumulated evidence suggests that VR serves as a "bridge" linking theoretical knowledge with real-world clinical practice, offering students the opportunity to transition safely from passive learning to the active performance of procedures (Pottle, 2019; Liu, 2024).

In many studies, VR is described not as a replacement, but as a significant extension of classical simulators and task trainers (Alghanaim, 2025). While traditional High-Fidelity Simulators require physical presence in simulation centers and are costly to maintain, VR offers a scalable solution that can be deployed regardless of geographic location (Pottle, 2019; Radianti et al., 2020). Documentation highlights the high efficacy of VR in expanding learning opportunities in anatomy, surgery, and specialized procedures (Kyaw et al., 2019; Zhao et al., 2021; Li et al., 2025). Immersive systems based on HMDs allow for the creation of a fully controlled educational environment that enhances the students' sense of presence and engagement (Radianti et al., 2020; Pedram et al., 2023).

A key outcome reported in the literature is the positive impact of VR on patient safety (Pottle, 2019). By enabling students to practice in a low-risk environment, VR allows them to make mistakes and learn from them without real-world medical consequences (Pottle, 2019). Numerous interventions have shown that students using VR demonstrate higher levels of proficiency and confidence before proceeding to live procedures (Kyaw et al., 2019; Tay et al., 2025).

Standardization of training is another pattern emerging from the analyzed texts (Pedram et al., 2023). Unlike traditional clinical practice, where patient cases are unpredictable, VR offers structured scenarios where every learner encounters identical conditions and educational challenges (Pedram et al., 2023). This ensures objective assessment and a uniform level of competence across the student group (Pedram et al., 2023). Additionally, research emphasizes the importance of repeatability; VR enables multiple, virtually unlimited repetitions of a given procedure "on demand," which is crucial for achieving technical proficiency (Pottle, 2019; Kyaw et al., 2019).

Comparative analysis indicates specific differences between VR, Augmented Reality (AR), and traditional simulators (Kyaw et al., 2019). IVR is reported to be particularly effective regarding measurable learning outcomes (objective teaching results) and positive subjective feedback compared to traditional methods (Kyaw et al., 2019; Foronda et al., 2024). While AR is identified as a promising tool for providing repeatable experiences, most research focuses on IVR as the technology with the greatest transformative potential in surgical and anatomical education (Kyaw et al., 2019).

In relation to high-fidelity simulators, VR demonstrates advantages in logistical and economic aspects - requiring less space and fewer technical staff while offering comparable or superior results in knowledge and skill acquisition (Pottle, 2019; Foronda et al., 2024). However, some studies point to a lack of skill transfer in VR systems with low-standard haptic (tactile) feedback, which remains a significant drawback compared to physical task trainers (Kyaw et al., 2019).

Despite its high procedural effectiveness, research results indicate certain limitations of VR in the area of interpersonal interaction (Mundok et al., 2026; Xu & Yang, 2025). Although VPs are successfully used to teach communication and empathy, they do not fully replace the complexity of real human contact (Mundok et al., 2026; Yamada et al., 2026). Traditional methods, such as working with SPs, offer authentic emotions and communicative nuances that are currently standardized and simplified in VR systems (Mundok et al., 2026). Consequently, VR is viewed as a preparatory tool that structures the process of learning patient relationships but requires supplementation in actual clinical settings (Mundok et al., 2026; Xu & Yang, 2025).

3.2 Impact of VR on Technical Competence Development and Clinical Procedure Training

Evidence from across the reviewed literature indicates that vr is an effective modality for enhancing technical skills and procedural knowledge in medical education (Kyaw et al., 2019; Zhao et al., 2021; Zhang et al., 2025). Research consistently identifies improvements in psychomotor performance, including manual coordination and spatial orientation, particularly when compared to traditional educational methods (Kim & Kim, 2023; Zhao et al., 2021).

Across multiple medical disciplines, VR interventions have been reported to significantly improve manual coordination and dexterity (Kim & Kim, 2023). In surgical training, meta-analytic data suggest that VR simulators contribute to higher precision and reduced error rates during manual tasks (Kim & Kim, 2023). Similarly, studies focusing on anatomy education indicate that IVR environments enhance students' spatial orientation and their ability to visualize complex three-dimensional structures compared to 2D traditional methods (Zhao et al., 2021). For instance, students utilizing VR for anatomy training demonstrated superior performance in identifying anatomical relationships and spatial configurations (Zhao et al., 2021).

Surgery and Orthopedics: Multiple systematic reviews report that VR training leads to significantly better objective learning outcomes in clinical surgery and orthopedic education (Zhang et al., 2025; Li et al., 2025). VR simulators are particularly noted for improving surgical proficiency, such as in tendon repair and bone surgery (Li et al., 2025).

Anesthesiology and Emergency Medicine: Research indicates that VR is effective for teaching high-stakes procedures, including cardiopulmonary resuscitation (CPR), trauma decision-making, and neonatal resuscitation (Pottle, 2019; Hou et al., 2025). In emergency medicine, VR-based simulators have been utilized to assess competence and improve the management of agitated patients (Tay et al., 2025).

Radiology: Evidence suggests that 3D VR simulations provide radiologic technology students with enhanced skills in assessing image quality and understanding radiographic positioning (O'Connor et al., 2021).

Several studies compared VR to traditional education (e.g., lectures, textbooks, or 2D videos) and physical simulators (Kyaw et al., 2019). Systematic reviews and meta-analyses generally report that VR is more effective than traditional methods for skill acquisition (Kyaw et al., 2019). When compared to traditional simulation - such as manikin-based training or SPs - VR was often found to be at least as effective, and in some cases superior, in terms of objective learning outcomes and learner engagement (Foronda et al., 2024). Specifically, in orthopedic education, VR training resulted in higher engagement and better skill acquisition than traditional methods (Li et al., 2025).

Findings regarding the efficiency and longevity of VR-based training highlight several key patterns:

Learning Time: Evidence from multiple studies suggests that VR can lead to faster acquisition of procedural skills, potentially reducing the total training time required to reach a specific level of proficiency compared to traditional methods (Li et al., 2025; Pottle, 2019).

Knowledge Retention: Studies have reported that VR demonstrates significant long-term effects on medical knowledge acquisition (Zhang et al., 2025). Follow-up assessments, including one-year post-intervention, indicate that skills and knowledge gained through VR are well-retained over time (Liu, 2024).

Transfer of Skills: A critical finding across the literature is the successful transfer of skills from the virtual environment to physical clinical practice (Kyaw et al., 2019; Pottle, 2019). In surgical training, trainees who practiced on VR simulators showed improved performance in real-world clinical tasks and procedural accuracy (Pottle, 2019). Furthermore, VR has been identified as a functional "bridge" between theoretical medical education and practical clinical application (Liu, 2024).

Despite these positive outcomes, some studies noted limitations, such as a lack of skill transfer in specific contexts involving haptic feedback or inconsistent results regarding the impact of VR on learner emotions related to clinical skills (Zhao et al., 2021; Lin et al., 2024). Overall, however, the synthesis of current research supports the effectiveness of VR as a robust tool for developing technical competencies and mastering clinical procedures across various medical disciplines (Zhang et al., 2025).

3.3 VR as a Tool for Developing Clinical Empathy: Immersive Simulations of Patient Experiences

Based on the literature review, VR is increasingly utilized in medical education as a tool enabling students to directly "experience" the patient's perspective (Liu, 2024; Alghanaim et al., 2025). Research indicates that immersive simulations allow participants to assume the roles of individuals struggling with various conditions and impairments, aiming to deepen the understanding of the subjective experience of illness (Xu & Yang, 2025).

Many identified interventions focus on simulating processes related to aging and neurodegenerative diseases, such as dementia (Alghanaim et al., 2025). For instance, the use of "Embodied Labs" modules allowed medical and nursing students to virtually embody a patient at the end of life or an elderly individual with progressive cognitive and sensory deficits (Elzie & Shaia, 2021). A similar approach was applied to simulations of physical impairments, where audiology students used VR technology combined with haptic gloves to experience hearing loss and manual dexterity limitations typical of geriatric patients (Alfakir et al., 2025).

A significant area of research concerns the use of VR in education regarding mental and neurological disorders (Alghanaim et al., 2025). The analyzed publications describe simulations that allow participants to experience symptoms of psychosis and schizophrenia, including auditory and visual hallucinations (Alghanaim et al., 2025). Participants in these studies could feel the disorientation and communication difficulties associated with these states, which in many cases led to a shift in attitudes toward the mentally ill and a reduction in stigmatization (Alghanaim et al., 2025). Furthermore, recent experimental studies have addressed the topic of chronic pain, using narrative VR experiences to familiarize students with the daily struggles of patients suffering from pain of undetermined etiology (Xu & Yang, 2025).

Regarding educational effects, evidence from multiple studies indicates an increase in empathy levels among students following VR interventions (Alghanaim et al., 2025; Xu & Yang, 2025). Analyses often distinguish the impact of technology on two primary components of empathy:

Cognitive Empathy: Participants reported a better understanding of the patient's life situation and the mechanisms behind their behaviors (Xu & Yang, 2025). VR simulations fostered perspective-taking, which translated into higher scores on standardized scales, such as the Jefferson Scale of Empathy (Alghanaim et al., 2025).

Emotional (Affective) Empathy: Research demonstrated that immersive experiences can evoke strong emotional responses in students, such as compassion or concern (Xu & Yang, 2025). Some studies utilized neurological and physiological measurements, pointing to an increase in so-called neurological immersion associated with the release of oxytocin during engaging VR narratives (Keckler et al., 2025).

VR also proves effective as a tool for training in clinical communication (Alghanaim et al., 2025). By participating in simulated interviews with "virtual patients," students could practice interpersonal skills in a safe, repeatable environment (Alghanaim et al., 2025). Results suggest that such training increases students' confidence in handling difficult situations, such as conversations with agitated or aggressive patients (Tay et al., 2025).

Despite the reported benefits, the materials indicate several methodological limitations in current research on empathy in VR. Many authors highlight:

- The dominance of pilot studies with small sample sizes ($n \leq 70$) (Alghanaim et al., 2025).
- A lack of long-term assessment of effect durability - most measurements are taken immediately after the simulation (Xu & Yang, 2025; Alghanaim et al., 2025).
- Reliance primarily on subjective self-report scales, which may be subject to social desirability bias (Mundok et al., 2026).
- The heterogeneity of technologies used (ranging from simple 360° videos to fully interactive systems with HMDs), which complicates direct comparison of results across studies (Zhang et al., 2025).
- The occurrence of negative side effects in some participants, such as cybersickness (simulator sickness), which may interfere with the learning process and research outcomes (Zhang et al., 2025; Alfakir et al., 2025).

3.4 The Risk of the “Empathy Gap”. Can virtual environments weaken the relational aspects of medicine?

Evidence across several studies suggests that IVR training can lead to an over-emphasis on technical milestones at the expense of humanistic care (Pottle, 2019). In surgical and orthopedic training, VR simulators are frequently used to enhance psychomotor skills and procedural engagement (Kim & Kim, 2023; Li et al., 2025). However, findings indicate that such environments often prioritize the "technical" over the "social," potentially leading to a desensitization toward the patient's lived experience (Pottle, 2019). This phenomenon is particularly noted in high-stakes clinical scenarios, such as agitation management, where students initially report fear or stigma (Tay et al., 2025). While VR provides a low-risk environment for repeated practice, there is a noted risk that learners may come to view the VP as a set of clinical tasks to be completed rather than a person requiring empathic engagement (Pottle, 2019).

The impact of VR on "bedside manner" and communication skills varies significantly depending on the simulation design (Alghanaim, 2025). In some contexts, VR is reported to improve NTS, such as

interprofessional communication and reflection (Alghanaim, 2025). For instance, simulations involving "virtual patients" have been used to enhance clinical judgment and decision-making (Yamada et al., 2026). However, research also highlights that these virtual interactions can be limited by the technology's inability to replicate the nuanced social cues of a real-world doctor-patient relationship (Yamada et al., 2026).

Specific interventions, such as embodying a patient with a terminal illness or experiencing the sensory distortions of psychosis, are designed to bridge this gap (Elzie & Shaia, 2021; Zare-Bidaki et al., 2022). While these modules often report a significant increase in immediate affective empathy, researchers have noted that the "technological" nature of the experience can sometimes distract from the emotional weight of the encounter (Xu & Yang, 2025). In nursing education, for example, the use of VR to simulate neurologic symptoms showed increases in immersion and empathy, yet the sustainability of these relational gains remains a subject of ongoing evaluation (Keckler et al., 2025; Xu & Yang, 2025).

A recurring theme across the literature is the concern that VR might serve as a substitute for, rather than a supplement to, real-world clinical exposure (Pottle, 2019). During the COVID-19 pandemic, digital solutions were rapidly adopted to maintain education amidst clinical restrictions (Dhar et al., 2023; Goh & Sandars, 2020). While these tools effectively delivered standardized training, findings suggest that a reduction in contact with real patients can lead to an erosion of the professional socialization typically found in clinical settings (Pottle, 2019). In psychiatric education, where "standardized patients" (actors) are the traditional gold standard, VR and AR are viewed as potential tools for replicable experiences, but the lack of "real" human interaction is cited as a factor that may weaken the development of long-term relational skills (Zare-Bidaki et al., 2022; Xu & Yang, 2025).

The reviewed studies highlight a tension between the "efficiency" of VR and the "authenticity" of traditional simulation (Foronda et al., 2024). Multiple meta-analyses report that while VR often yields significantly better objective learning outcomes in clinical skills and anatomy compared to traditional methods (Kyaw et al., 2019; Zhao et al., 2021), its effect on the "affective domain" - including student emotions and attitudes - is less consistent (Zhao et al., 2021; Lin et al., 2024). For example, in radiography education, while 3D VR simulations were highly valued by students for technical practice, the findings emphasize that these should not replace the interpersonal learning inherent in clinical practice (O'Connor et al., 2021).

Furthermore, some studies indicate that the cognitive load associated with navigating complex VR hardware (such as HMDs) can temporarily overshadow the social learning objectives (Zhang et al., 2025). This imbalance suggests that while VR is an effective "bridge" between medical education and clinical practice (Liu, 2024), it carries a risk of narrowing the learner's focus to technical mastery, potentially neglecting the relational and empathic dimensions essential for patient-centered care (Pottle, 2019).

3.5 The Impact of VR on the Professional Socialization Process: Shaping the Medical Professional Identity

The reviewed literature indicates that VR serves as a transformative medium for professional socialization by allowing students to internalize professional norms and clinical responsibilities through immersive experiences (Pottle, 2019; Røe et al., 2025). Multiple studies report that VR interventions facilitate a fundamental shift in how learners perceive their roles, moving from passive observers to active participants within clinical narratives (Pottle, 2019; Elzie & Shaia, 2021).

Specifically, evidence from interventions utilizing "embodied labs" suggests that by virtually "becoming the patient," medical students experience first-hand the daily activities and symptoms of terminal illness (Elzie & Shaia, 2021). This significantly impacts their understanding of compassionate care (Elzie & Shaia, 2021). This process of virtual embodiment facilitates the internalization of medical ethics and the gravity of responsibility inherent in end-of-life conversations - areas where traditional training is often reported to fall short (Elzie & Shaia, 2021).

Across the reviewed studies, the impact of VR on the internalization of professional ethics is frequently linked to the technology's ability to simulate high-stakes or sensitive scenarios that are difficult to replicate in traditional settings (Pottle, 2019). For instance:

- **Mental Health:** VR simulations focused on psychosis and schizophrenia have been shown to shift medical students' attitudes, significantly reducing the stigma associated with mental illness (Marques et al., 2022; Zare-Bidaki et al., 2022).
- **Physical Limitations:** By replicating challenges such as hearing loss or manual dexterity limitations, students develop a deeper commitment to patient-centered care (Alfakir et al., 2025).

Observational learning and the modeling of professional behavior are central themes identified in the findings (Pottle, 2019). VR provides a standardized platform for practicing complex clinical interactions, such as:

1. Managing patient agitation in psychiatric settings (Tay et al., 2025).
2. Navigating shared decision-making in pediatrics (Pottle, 2019).

These simulations allow learners to model their behavior after established professional standards in a low-risk, repeatable environment (Pottle, 2019; Tay et al., 2025). The evidence indicates that such training increases self-efficacy in managing stressful clinical encounters, which is a critical component of a developing professional identity (Tay et al., 2025).

The research also highlights the role of mentors and the "hidden curriculum" within digital environments (Pottle, 2019). VR facilitates shared clinical experiences that provide standardized mentorship at scale, independent of geography (Pottle, 2019). Findings suggest that VR is particularly effective for IPE, where students from different healthcare disciplines (e.g., medicine, nursing, physiotherapy) interact within a virtual world to practice NTS and ethical collaboration (Alghanaim, 2025; Pottle, 2019).

Furthermore, the research indicates that VR education increases "neurologic immersion," which is associated with more effective socialization and the development of empathy (Keckler et al., 2025). Students participating in VR-based simulations report higher levels of engagement and a more profound sense of presence compared to traditional lecture-based methods (Mundok et al., 2026; Pottle, 2019).

While traditional simulation remains a cornerstone of training, multiple studies conclude that VR offers a cost-effective and repeatable alternative (Pottle, 2019; Kyaw et al., 2019). It supports the longitudinal development of professional identity by providing consistent access to complex social and clinical scenarios that prepare students for the realities of the medical profession (Pottle, 2019).

3.6 VR in the Development of Communication Competencies: Simulating Physician - Patient Interactions

The synthesis of findings across the reviewed studies indicates that VR is an increasingly effective modality for developing communication skills in healthcare education, particularly through the simulation of complex and high-stakes physician - patient interactions (Pottle, 2019; Alghanaim, 2025). Evidence suggests that VR environments provide a standardized and safe platform for students to practice clinical dialogue, ranging from routine consultations to emotionally taxing scenarios (Pottle, 2019; Tay et al., 2025).

Across several interventions, VR has been identified as a significant tool for training in "difficult" patient encounters (Tay et al., 2025). Multiple studies highlight the use of VR to manage agitated or aggressive patients, particularly in psychiatric settings (Tay et al., 2025).

- **Psychiatric Emergencies:** Students engaging in IVR simulations - such as managing a patient experiencing psychosis or acute agitation - report increased confidence and improved de-escalation skills (Tay et al., 2025). These digital environments allow learners to experience the physiological and psychological pressure of a crisis without the real-world risks associated with unpredictable clinical behavior (Pottle, 2019; Tay et al., 2025).

- **Pediatrics:** Evidence from training modules shows that VR can be used to navigate vaccine hesitancy (Pottle, 2019). Residents who practiced addressing parental refusal in a virtual environment demonstrated improved communication techniques and higher rates of vaccine acceptance in subsequent clinical practice (Pottle, 2019).

The use of VR for training in the delivery of "bad news" and sensitive end-of-life conversations is another consistent theme (Elzie & Shaia, 2021). Several studies utilized "embodied labs," where students virtually occupied the role of a patient with a terminal illness (e.g., advanced-stage cancer) (Elzie & Shaia, 2021). This perspective-taking approach was found to significantly alter students' communicative strategies (Elzie & Shaia, 2021). Participants reported that the visceral experience of "becoming the patient" helped them internalize the nuances of compassionate communication, leading to a more patient-centered approach when discussing prognosis and palliative care (Elzie & Shaia, 2021).

A significant advancement reported in recent literature is the integration of AI-driven avatars and VPs (Rodda et al., 2025; Yamada et al., 2026). Findings indicate that these digital entities offer a scalable and repeatable alternative to human-based training (Pottle, 2019; Yamada et al., 2026).

- **History-Taking:** AI-driven VPs were used to simulate psychiatric interviews, allowing students to practice history-taking and diagnostic questioning (Rodda et al., 2025).

- **Consistency:** These avatars provide consistent feedback and can be programmed to display specific emotional states or symptoms, such as the flat affect seen in schizophrenia or the disorganized speech characteristic of psychosis (Rodda et al., 2025).

The assessment of communication quality in these environments is conducted through both objective and subjective measures:

- **Subjective:** Improved scores on standardized scales, such as the Jefferson Scale of Empathy (JSE) (Mundok et al., 2026; Alfakir et al., 2025).

- **Objective:** Analysis of gaze behavior, verbal response times, and the selection of non-confrontational language (Yamada et al., 2026). For example, in simulations involving agitated patients, proficiency was measured by the student's ability to maintain physical distance and use calming verbal cues (Tay et al., 2025).

When comparing VR to traditional methods involving SPs, the literature reveals distinct advantages:

- **Psychological Safety:** Medical students often feel less judged and more willing to experiment with different strategies when interacting with a virtual avatar (Pottle, 2019). VR offers a space to "fail and retry" without social consequences (Pottle, 2019).

- **Logistics:** While SPs provide high social realism, they are resource-intensive and difficult to standardize (Pottle, 2019; Yamada et al., 2026). VR is described as a cost-effective, "simulation on demand" solution (Pottle, 2019).

Finally, evidence suggests that VR environments facilitate IPE (Alghanaim, 2025). In these simulations, students from different disciplines (e.g., nursing and medicine) interact within a shared virtual space (Alghanaim, 2025). These interventions improve NTS, including team communication and shared decision-making, which are often difficult to coordinate in physical simulation centers due to geographical and scheduling constraints (Alghanaim, 2025; Pottle, 2019).

3.7 Socio-economic Barriers to VR Implementation and Technology Accessibility in Medical Education

The analysis of the collected body of evidence indicates a number of economic and infrastructural challenges that determine both the pace and the scope of implementing vr - based solutions in the training of medical personnel (Pottle, 2019; Radianti et al., 2020). Although this technology is widely perceived as transformative (Goh & Sandars, 2020), its widespread adoption encounters barriers related to costs, regional disparities in wealth, and the specific funding structures of educational institutions (Pottle, 2019).

The literature repeatedly emphasizes that traditional methods of clinical simulation are highly resource-intensive and require substantial financial and human resources (Pottle, 2019; Yamada et al., 2026). In this context, vr is often presented as a potentially cost-effective alternative, offering the possibility of standardized, on-demand training (Pottle, 2019). Nevertheless, the entry barrier associated with initial financial investments remains significant (Pottle, 2019). The documentation indicates that the development of VR systems requires not only the purchase of HMDs, but also investments in dedicated software, physical training space, and continuous technical support (Pottle, 2019).

Systematic studies further highlight that the high cost of high-end HMDs and computers with substantial processing power limits their accessibility when compared with cheaper, mobile-based solutions (Radianti et al., 2020). However, it has also been observed that the decreasing trend in VR hardware prices in recent years may facilitate broader adoption of these technologies in the future (Pottle, 2019).

The reviewed evidence reveals a clear disparity in VR implementation between countries with different income levels (Pottle, 2019; Radianti et al., 2020). The majority of the analyzed studies and implementations were conducted in high-income countries, such as the United States (Elzie & Shaia, 2021), the United Kingdom (Pottle, 2019), Singapore (Kyaw et al., 2019; Jiang et al., 2022), and Norway (Radianti et al., 2020; Røe et al., 2025). Systematic reviews indicate that institutions in these regions possess budgets that enable both experimental and routine use of advanced immersive systems (Jiang et al., 2022; Tay et al., 2025).

In contrast, low- and middle-income countries appear less frequently in the body of research on VR, which suggests difficulties in accessing modern digital infrastructure (Pottle, 2019). Even in dynamically developing countries, financial barriers are identified as a major factor limiting innovation in medical education (Pottle, 2019). The lack of stable funding and limited technological resources in these regions further widen the gap in the quality of training for physicians and nurses compared to developed countries (Pottle, 2019).

Although the provided texts focus less directly on comparisons between the public and private sectors, an observable pattern emerges indicating the advantage of institutions with flexible funding for innovation. Private universities and prestigious research centers in countries such as Singapore (e.g., Lee Kong Chian

School of Medicine) more frequently report participation in multi-center technological projects (Kyaw et al., 2019; Jiang et al., 2022). By contrast, in the public sector - particularly under conditions of budgetary pressure - VR is sometimes perceived as a risky investment unless its direct cost advantage over traditional methods can be clearly demonstrated (Pottle, 2019).

The phenomenon of the digital divide manifests itself in medical education on two levels: institutional and individual (Røe et al., 2025). At the institutional level, limited access to high-speed internet connections and modern equipment prevents the implementation of VR systems based on cloud collaboration or multi-user virtual environments (Pottle, 2019). At the individual level, students from less affluent backgrounds or regions with weaker digital infrastructure have fewer opportunities to acquire the digital competencies that are increasingly essential in contemporary medicine (Røe et al., 2025).

Research indicates that the COVID-19 pandemic accelerated the process of digitalization, while simultaneously highlighting disparities in technological preparedness among different institutions (Dhar et al., 2023; Goh & Sandars, 2020). The lack of standardization of VR tools and varying levels of technical support mean that access to advanced knowledge in fields such as anatomy or surgery increasingly depends on the financial capacity of a particular institution (Pottle, 2019). Consequently, despite the theoretical potential of VR to democratize medical education - through remote simulations and broader accessibility (Pottle, 2019) - in practice the technology may currently reinforce existing educational hierarchies resulting from economic barriers (Pottle, 2019).

3.8 VR as a Tool for the Globalization of Medical Education: Standardizing Clinical Training

Evidence identified in the literature indicates that VR plays a pivotal role in the globalization of medical education, offering standardization opportunities that transcend traditional geographical and institutional boundaries (Pottle, 2019; Alghanaim, 2025). The analysis of available materials highlights several key areas where this technology facilitates the unification and expansion of clinical training access on an international scale (Pottle, 2019; Kyaw et al., 2019).

Research indicates that VR enables the delivery of repeatable and standardized clinical training on demand, which is crucial in the face of increasing pressure on educational budgets and the necessity of maintaining high-quality instruction (Pottle, 2019). Documentation emphasizes that VR simulations allow for the creation of shared virtual clinical experiences that are independent of the participants' physical location (Pottle, 2019). This approach fosters the development of uniform competencies among future clinicians, regardless of where they receive their primary education (Pottle, 2019). In surgical education, including orthopedics, VR is viewed as a tool capable of supplementing or even replacing traditional methods by offering standardized training modules that can be deployed across various academic centers worldwide (Li et al., 2025; Pottle, 2019).

The literature notes that integrating VR into curricula promotes new forms of cross-institutional collaboration (Kyaw et al., 2019). Examples include initiatives such as the Digital Health Education Collaboration, which involves researchers and educators from multiple countries (e.g., Singapore, the UK, Sweden, and Poland) to develop and evaluate the efficacy of digital education methods (Kyaw et al., 2019).

- Collaborative Frameworks: This cooperation focuses on creating frameworks for technology-based teaching, which includes medical knowledge transfer and the enhancement of students' digital competencies through peer-assisted learning in virtual environments (Røe et al., 2025; Kyaw et al., 2019).
- Interprofessional Education: The development of multi-user virtual worlds allows for IPE sessions where students from different medical professions can train together in the same digital space, aligning teamwork standards at a global level (Alghanaim, 2025; Pottle, 2019).

Particular attention in the analyzed texts is given to VR's potential to democratize access to high-quality medical education in resource-limited regions (Pottle, 2019). Traditional clinical simulation methods are often resource-intensive and expensive, limiting their accessibility (Pottle, 2019; Yamada et al., 2026). VR is described as a cost-effective solution that allows for the infinite repetition of procedures without the need for expensive medical equipment or the employment of SP actors (Pottle, 2019; Kyaw et al., 2019). Consequently, universities in developing countries can offer students access to advanced clinical scenarios that were previously unattainable due to financial barriers or a lack of specialized personnel (Pottle, 2019).

The evidence suggests that the COVID-19 pandemic acted as a catalyst for the global adoption of VR in medical education (Dhar et al., 2023; Goh & Sandars, 2020). Amidst restrictions and the loss of access to traditional clinical facilities, universities worldwide were forced to rapidly adapt to digital solutions (Dhar et al., 2023; Goh & Sandars, 2020).

- Transformational Shift: VR became an essential component of this shift, ensuring the continuity of teaching and assessment under social distancing protocols (Goh & Sandars, 2020).
- Crisis Resilience: Experiences from this period demonstrated that VR can effectively support education during crises, providing a safe and controlled environment for the acquisition of practical skills (Goh & Sandars, 2020).

3.9 Regulations and Standards in Simulation Education: Establishing Frameworks for Digital Integration

The integration of VR into health professions education is increasingly governed by emerging standards and the oversight of global health and educational organizations (Pottle, 2019; Røe et al., 2025). Across the reviewed literature, there is a consistent emphasis on the transition from ad hoc technology use toward structured, SBME frameworks and standardized digital training protocols (Pottle, 2019).

Multiple studies indicate that VR is being positioned as a cornerstone of SBME due to its ability to provide repeatable, standardized clinical training on demand (Pottle, 2019). Evidence suggests that for VR to be effectively integrated into curricula, it must align with established simulation standards that prioritize defined learning objectives and objective outcome measures (Pottle, 2019).

Systematic reviews highlight that the use of IVR based on HMDs is increasingly scrutinized through the lens of standardized research guidelines, such as the PRISMA and PRISMA-ScR frameworks (Zhang et al., 2025; Jiang et al., 2022). This ensures the methodological validity of reported educational outcomes. Furthermore, digital medical training is evolving toward "blended" or "integrated" models, where effectiveness is evaluated against the Kirkpatrick model, standardizing the assessment of learner reactions, knowledge acquisition, and behavioral changes (Minouei et al., 2024).

The literature identifies several key organizations influencing the standards and adoption of digital health education:

- World Health Organization (WHO): The WHO is cited as a primary driver through its "Global Strategy on Digital Health 2020 - 2025," which encourages digital solutions to strengthen healthcare systems (Røe et al., 2025). Documents also reference WHO reports regarding the necessity of innovative care for chronic conditions and the role of technology in achieving global health targets (Pottle, 2019).
- Society for Simulation in Healthcare (SSH): Professional bodies like the SSH provide the methodological frameworks used to assess the quality of simulation programs (Foronda et al., 2024).
- Interprofessional Standards: The literature notes the application of IPE domains - such as ethical practice and collaborative working - as standard benchmarks for evaluating VR simulations in shared care settings (Alghanaim, 2025).
- Institutional Frameworks: Educational institutions are increasingly adopting standardized checklists, such as the MERSQI and JBI critical appraisal tools, to maintain the rigor of VR-based educational programs (Alghanaim, 2025; Hou et al., 2025).

A significant pattern observed across the analyzed studies is the recognized gap in long-term validation and certification of VR applications (Pedram et al., 2023). While many applications are feasible for short-term simulation, researchers emphasize a lack of standardized measures for long-term training effectiveness (Pedram et al., 2023).

The need for formal certification and systematic validation of VR-HMD systems is highlighted as a prerequisite for their full-scale integration into medical curricula (Pedram et al., 2023). Current research focuses on demonstrating that these technologies can meet the rigorous standards of clinical competency (Keckler et al., 2025). However, there is an expressed need for more robust, longitudinal data to establish permanent training standards (Pedram et al., 2023). Evidence suggests that while VR is increasingly used for competence assessment, the field is still moving toward a unified certification process that would ensure digital tools provide a "standardized clinical experience" equivalent to traditional simulation methods (Pedram et al., 2023).

3.10 The Future of VR in Medical Training: Integrating VR with Emerging Technologies

The synthesis of analyzed materials indicates that the future of VR in medical education is intrinsically linked to its integration with other advanced digital technologies (Goh & Sandars, 2020; Liu, 2024). The emerging evidence points toward a transition from isolated simulations to integrated educational ecosystems that combine VR with AI, haptic feedback, and hybrid models (Goh & Sandars, 2020; Pottle, 2019).

Literature reviews suggest that AI is viewed as a pivotal transformative component that will enable a shift toward adaptive learning (Goh & Sandars, 2020). Several publications report that the synergy between

VR and AI allows for the creation of Intelligent VPs capable of natural, dynamic interactions with the user (Rodda et al., 2025; Yamada et al., 2026).

- **Personalization:** These systems can generate personalized training scenarios tailored to the individual learner's pace and competency level (Rodda et al., 2025).

- **Automated Assessment:** In addition to simulating patient behavior, AI within VR environments can provide automated assessment of student performance, offering precise, real-time feedback (Pottle, 2019; Rodda et al., 2025).

A significant development trend noted in recent research is the implementation of advanced haptic feedback systems, which supplement visual immersion with tactile sensations (Kim & Kim, 2023; Alfakir et al., 2025).

- **Geriatrics and Audiology:** Examples include the use of haptic gloves to allow students to physically experience the manual dexterity limitations typical of geriatric patients (Alfakir et al., 2025).

- **Surgical Precision:** In surgical and robotic training, haptic devices are essential for realistically replicating tissue resistance, which directly improves manual coordination and procedural precision (Kim & Kim, 2023; Li et al., 2025). This integration creates a comprehensive training environment that bridges visual and motor perception (Li et al., 2025).

Materials highlight the rising importance of the "Digital Twin" concept in conjunction with VR (Liu, 2024). Although still in the early stages of adoption in education, reports suggest its potential to create virtual replicas of specific patients' anatomical structures or physiological systems (Liu, 2024).

- **High-Fidelity Simulation:** This allows for extremely high-fidelity simulations where students can practice clinical procedures on digital models before transitioning to actual practice (Liu, 2024; Pottle, 2019). Research emphasizes that VR serves here as a "bridge" connecting theoretical anatomical knowledge with practical clinical application (Liu, 2024).

A common theme across the analyzed studies is the evolution of VR toward hybrid and collaborative education (Pottle, 2019; Alghanaim, 2025). Following the rapid digital adaptation necessitated by the COVID-19 pandemic (Dhar et al., 2023; Goh & Sandars, 2020), there has been a marked increase in interest in multi-user virtual worlds (Pottle, 2019; Alghanaim, 2025).

- **Collaborative Learning:** These solutions allow for shared clinical simulations where participants occupy the same virtual space regardless of their physical location (Pottle, 2019; Alghanaim, 2025).

- **Interprofessional Education:** Evidence suggests that this approach fosters IPE, enabling students of medicine, nursing, and other health professions to jointly practice NTS and teamwork under standardized conditions (Pottle, 2019; Alghanaim, 2025).

The synthesis of results indicates a strong drive toward full curriculum integration (Pottle, 2019). Research reports that the future of this technology depends on its ability to provide repeatable, standardized experiences that can be scaled globally (Kyaw et al., 2019; Pottle, 2019).

- **Overcoming Barriers:** Technological development is moving toward eliminating technical hurdles such as cybersickness and increasing accessibility through standalone VR headsets (Radianti et al., 2020; Pottle, 2019).

- **Simulation Centers:** A pattern is emerging where advanced VR systems are becoming integral components of medical simulation centers (Pottle, 2019), augmenting traditional task trainers and mannequins with a narrative and emotional layer, which is crucial for developing clinical empathy and professional socialization (Pottle, 2019; Elzie & Shaia, 2021).

4 Discussion

The transition from traditional apprenticeship models to contemporary educational paradigms represents one of the most significant shifts in the history of medical training (Pottle, 2019). The evidence reviewed across various medical and nursing disciplines suggests that VR is not merely a supplementary tool but a transformative catalyst in the move toward SBME (Pottle, 2019; Liu, 2024). By serving as a functional bridge between theoretical anatomical knowledge and the complexities of clinical practice, immersive technologies provide a safe environment for students to move from the role of a passive observer to that of an active participant (Liu, 2024). This evolution is particularly evident in the departure from the historical "See One, Do One, Teach One" model toward a structured, repeatable, and standardized framework where technical proficiency can be honed without compromising patient safety (Pottle, 2019). The findings indicate that the value of VR lies in its ability to offer a scalable solution that transcends geographic and institutional

boundaries, allowing for a democratization of high-quality simulation that was previously limited by the high costs and logistical constraints of physical high-fidelity simulators (Pottle, 2019; Alghanaim, 2025).

The educational and behavioral impacts of VR are rooted in the psychological sense of presence and the immersive nature of the medium (Pottle, 2019; Mundok et al., 2026). IVR utilizing HMDs fosters a level of engagement and narrative transportation that screen-based simulations fail to replicate (Pottle, 2019). The reviewed studies highlight that this heightened engagement directly influences cognitive and behavioral outcomes, such as improved self-efficacy and decision-making in high-stakes clinical scenarios (Tay et al., 2025; Alghanaim, 2025). For instance, in emergency medicine and psychiatric emergencies, students who engage in VR simulations for managing agitated or aggressive patients report significantly higher levels of confidence and improved de-escalation skills (Tay et al., 2025). This behavioral adaptation is made possible by the safe, low-risk nature of the virtual environment, which encourages students to experiment with different interpersonal strategies and "fail" without real-world medical or social consequences (Pottle, 2019). Such reflective learning processes allow students to internalize procedural milestones while managing the physiological and psychological pressures of a crisis, effectively preparing them for the unpredictable nature of actual clinical encounters (Pottle, 2019).

A central theme emerging from the literature is the role of VR in the professional socialization of medical students and the formation of their professional identity (Røe et al., 2025). Professional socialization involves the internalization of professional norms, ethics, and clinical responsibilities - areas where traditional training often falls short due to the difficulty of replicating sensitive or terminal scenarios (Elzie & Shaia, 2021). The use of virtual embodiment, specifically through "Embodied Labs" modules, allows students to virtually "become the patient," experiencing the daily struggles, symptoms, and sensory distortions associated with terminal illness, aging, or psychosis (Elzie & Shaia, 2021; Zare-Bidaki et al., 2022). This first-hand experience of the patient's perspective facilitates a deeper commitment to patient-centered care and helps students internalize the gravity of responsibility inherent in end-of-life conversations (Elzie & Shaia, 2021). By modeling professional behavior in these immersive clinical narratives, students move beyond rote learning to a more visceral understanding of compassionate care, which is a critical component of their developing identity as healthcare providers (Elzie & Shaia, 2021; Røe et al., 2025).

Furthermore, the technology-mediated environment introduces a "hidden curriculum" that influences professional socialization and interprofessional collaboration (Pottle, 2019; Alghanaim, 2025). Multi-user virtual worlds enable IPE sessions where students from medicine, nursing, and other health professions can jointly practice NTS, teamwork, and ethical collaboration within a shared digital space (Alghanaim, 2025). These shared clinical experiences provide standardized mentorship at scale, ensuring that students are exposed to uniform professional standards regardless of their physical location (Pottle, 2019). This synchronization of educational standards promotes a global professional culture characterized by ethical practice and collaborative working (Alghanaim, 2025). However, the findings also point to the emergence of a "neurologic immersion" mechanism, where engaging VR narratives are associated with the release of oxytocin, potentially providing a neurobiological foundation for the development of empathy and social bonding in virtual environments (Keckler et al., 2025).

Despite these social benefits, the literature identifies a persistent risk known as the "empathy gap" or the potential for desensitization within virtual environments (Mundok et al., 2026). Evidence suggests that a heavy reliance on VR training can lead to an over-emphasis on technical milestones at the expense of humanistic care (Pottle, 2019). In fields like surgery and orthopedics, where VR is extensively used to enhance psychomotor skills and procedural engagement, there is a noted risk that learners may begin to view the VP as a set of clinical tasks to be completed rather than a person requiring empathic engagement (Pottle, 2019). The technological nature of the encounter can sometimes distract from the emotional weight of the clinical situation, leading to a prioritization of the "technical" over the "social" (Alghanaim, 2025). This imbalance is further complicated by the cognitive load associated with navigating complex VR hardware, which can temporarily overshadow the social and relational learning objectives (Zhang et al., 2025). It is essential, therefore, to recognize that while VR is an effective preparatory tool, it cannot fully replace the authentic emotional distance and communicative nuances of real human contact provided by standardized patients or actual clinical exposure (Yamada et al., 2026; Liu, 2024).

The technological design of VR systems plays a decisive role in determining educational and social outcomes (Radianti et al., 2020). The level of immersion and the realism of simulations are cited as key factors in fostering perspective-taking and increasing empathy (Xu & Yang, 2025; Mundok et al., 2026). Interactive patient avatars and narrative-based scenarios allow for the simulation of complex social cues and emotional

states, such as the flat affect or disorganized speech seen in mental health disorders (Zare-Bidaki et al., 2022; Rodda et al., 2025). Advanced haptic feedback technologies are also emerging as a critical component, supplementing visual immersion with tactile sensations (Alfakir et al., 2025). In surgical and robotic training, haptic devices are essential for replicating tissue resistance, which directly improves manual coordination and precision (Kim & Kim, 2023; Li et al., 2025). Similarly, in geriatrics, haptic gloves allow students to physically experience the manual dexterity limitations of elderly patients, bridging the gap between visual perception and motor understanding (Alfakir et al., 2025). The integration of AI-driven avatars further enhances the scalability of these simulations, offering repeatable and consistent training for history-taking and psychiatric interviews (Rodda et al., 2025; Yamada et al., 2026).

However, the widespread adoption of VR is hindered by significant socio-economic and institutional barriers (Pottle, 2019). The high implementation and maintenance costs associated with high-end HMDs, dedicated software, and continuous technical support create a significant entry barrier for many educational institutions (Pottle, 2019; Alghanaim, 2025). This has led to a "digital divide" in medical education, where institutions in high-income countries have budgets that enable routine use of advanced immersive systems, while universities in low- and middle-income countries face difficulties in accessing modern digital infrastructure (Pottle, 2019; Radianti et al., 2020). This disparity may currently reinforce existing educational hierarchies, as students from less affluent backgrounds or regions have fewer opportunities to acquire the digital competencies essential for contemporary medicine (Pottle, 2019; Røe et al., 2025). Institutional resistance to pedagogical change and the lack of standardization of VR tools further complicate the integration process (Pottle, 2019). While the COVID-19 pandemic acted as a catalyst for digitalization and forced institutions to rapidly adapt to digital solutions, it also highlighted the varying levels of technological preparedness across different regions (Dhar et al., 2023; Goh & Sandars, 2020).

The current evidence base on VR in medical education possesses several methodological and conceptual limitations (Alghanaim, 2025). Many of the reviewed studies are pilot investigations with small sample sizes ($n \leq 70$), which limits the generalizability of their findings (Alghanaim, 2025; Mundok et al., 2026). Furthermore, there is a lack of long-term assessment of the durability of the educational and relational effects; most measurements are taken immediately after the simulation, leaving the sustainability of empathy gains and professional identity development a subject of ongoing evaluation (Xu & Yang, 2025; Mundok et al., 2026). Much of the research relies on subjective self-report scales, such as the Jefferson Scale of Empathy, which may be subject to social desirability bias (Mundok et al., 2026). Additionally, the heterogeneity of the technologies used - ranging from simple 360-degree videos to fully interactive IVR systems - complicates the direct comparison of results across studies (Dhar et al., 2023; Zhang et al., 2025). There is also limited research on the longitudinal impact of VR on socialization and the balance between simulation-based training and real patient interaction (Røe et al., 2025).

Future research should prioritize longitudinal studies to explore the long-term impact of VR on professional identity formation and the durability of empathy enhancements (Pedram et al., 2023; Xu & Yang, 2025). Comparative studies between VR-based training and traditional clinical training are necessary to better understand the transfer of skills and the ideal balance between virtual and physical practice (Foronda et al., 2024). Cross-cultural analyses of VR adoption would provide valuable insights into how different professional cultures and socio-economic contexts influence the implementation of immersive technologies (Pottle, 2019). Furthermore, research should investigate the synergy between VR and other emerging technologies, such as AI and "Digital Twins," to create more personalized and high-fidelity educational ecosystems (Liu, 2024; Goh & Sandars, 2020). Establishing robust, longitudinal data and unified certification standards for VR systems will be a prerequisite for their full-scale integration into medical curricula and for ensuring that digital tools provide a standardized clinical experience equivalent to traditional methods (Pedram et al., 2023).

The broader socio-technological implications of these findings suggest that VR is evolving into a foundational platform for the global synchronization of medical education (Pottle, 2019). By enabling the creation of shared virtual clinical experiences, VR promotes inclusivity and allows for the democratization of high-quality training (Pottle, 2019). This digital transformation represents an innovation in SBME that supports the development of both the technical and empathetic components of professionalism (Alghanaim, 2025). However, the future relationship between technological innovation and patient-centered care will depend on the ability of educators to maintain a balance between technical mastery and the relational dimensions of medicine (Pottle, 2019). As medical training environments become increasingly technologically mediated, the challenge will be to ensure that the "hidden curriculum" emphasizes humanistic care and that the professional identity of future physicians remains rooted in empathy and the authentic nuances of the

doctor-patient relationship (Elzie & Shaia, 2021; Mundok et al., 2026; Alghanaim, 2025). These developments have significant implications for technology-enabled rehabilitation and the broader digital health landscape, suggesting a future where immersive technologies are integral to the professional culture and clinical excellence of the global healthcare workforce (Røe et al., 2025).

5. Conclusions

The integration of VR into medical education represents a profound paradigm shift, transitioning clinical training from the traditional apprenticeship models defined by the "See One, Do One, Teach One" approach toward a structured, SBME framework. This review demonstrates that immersive virtual environments serve as a transformative catalyst and a functional "bridge" connecting theoretical anatomical knowledge with the complexities of real-world clinical practice. By providing a safe, repeatable, and fully controlled digital ecosystem, VR allows for the infinite repetition of high-stakes procedures on demand, thereby enhancing patient safety and ensuring a standardized quality of training that transcends geographic and institutional boundaries. The synthesis of current evidence confirms that IVR, particularly through the use of HMDs, offers a level of presence and psychological engagement that traditional screen-based simulations cannot replicate. Consequently, these technologies are no longer viewed as mere novelties but as essential tools for the active performance of procedures and the internalization of clinical roles in a low-risk environment.

The implications for professional socialization and empathy development are equally significant, as VR facilitates a fundamental shift in how learners perceive their roles - moving from passive observers to active participants. Through the process of virtual embodiment and "Embodied Labs," students can directly experience the patient's perspective, facilitating the internalization of professional ethics and a deeper commitment to patient-centered care. While these interventions have been shown to increase both cognitive and affective empathy, as evidenced by improved scores on the Jefferson Scale of Empathy and the release of oxytocin during engaging narratives, the review also identifies a persistent "empathy gap." There is a documented risk that a heavy reliance on virtual environments may lead to an over-emphasis on technical milestones at the expense of humanistic care. This tension between technical efficiency and relational authenticity suggests that while VR is an effective preparatory tool for communication and "bedside manner," it must be supplemented by actual clinical exposure to capture the full complexity of human interaction and prevent the desensitization of future physicians.

On an institutional and policy level, the adoption of VR is increasingly governed by emerging standards and global frameworks, such as the World Health Organization's "Global Strategy on Digital Health 2020 - 2025." However, the rapid digitalization catalyzed by the COVID-19 pandemic has simultaneously exposed a significant "digital divide." High implementation costs, infrastructure requirements, and the need for continuous technical support create socio-economic barriers that may reinforce existing educational hierarchies between high-income countries and resource-limited regions. Despite these challenges, VR promotes the globalization of medical education by facilitating IPE and shared clinical experiences within a "hidden curriculum" that fosters ethical collaboration across diverse healthcare disciplines. Policy efforts must therefore focus on creating unified certification processes and validation frameworks to ensure that digital tools provide a standardized clinical experience equivalent to traditional simulation methods while addressing the disparities in technological accessibility.

Future research directions must prioritize the collection of robust, longitudinal data to assess the long-term sustainability of relational gains and professional identity formation. Current literature is often limited by small sample sizes and a reliance on subjective self-report scales, necessitating more rigorous methodological approaches to establish permanent training standards. Furthermore, the future of clinical training lies in the synergy between VR and other emerging technologies, including AI-driven avatars for personalized adaptive learning and "Digital Twins" for high-fidelity anatomical replicas. The integration of advanced haptic feedback systems will be crucial to overcoming current limitations in skill transfer by bridging visual and motor perception. Ultimately, the broader social significance of VR in medical education depends on the ability of institutions to balance technological innovation with the preservation of the humanistic dimensions of medicine, ensuring that the global healthcare workforce remains rooted in both technical excellence and authentic clinical empathy.

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REFERENCES

- Alfakir, R., Holt, G., Mason, L., McGuckin, L., Chen, Y., Hawkins, G., Weisbrod, L., & Trehub, A. (2025). Promoting empathy in audiology education through virtual reality and tactile technologies: A pilot study for patient-centered care in individuals with hearing loss and manual dexterity limitations. *Medical Science Educator*, 35(4), 2011–2019. <https://doi.org/10.1007/s40670-025-02403-x>
- Alghanaim, N., Hart, J., & Finn, G. (2025). Scoping review: The effectiveness of interprofessional virtual reality simulation. *Journal of Medical Education and Curricular Development*, 12, Article 23821205251346327. <https://doi.org/10.1177/23821205251346327>
- Dhar, E., Upadhyay, U., Huang, Y., Uddin, M., Manias, G., Kyriazis, D., Wajid, U., AlShawaf, H., & Syed Abdul, S. (2023). A scoping review to assess the effects of virtual reality in medical education and clinical care. *Digital Health*, 9, Article 20552076231158022. <https://doi.org/10.1177/20552076231158022>
- Elzie, C. A., & Shaia, J. (2021). A pilot study of the impact of virtually embodying a patient with a terminal illness. *Medical Science Educator*, 31(2), 665–675. <https://doi.org/10.1007/s40670-021-01243-9>
- Foronda, C. L., Gonzalez, L., Meese, M. M., Slamon, N., Baluyot, M., Lee, J., & Aebersold, M. (2024). A comparison of virtual reality to traditional simulation in health professions education: A systematic review. *Simulation in Healthcare: Journal of the Society for Simulation in Healthcare*, 19(1S), S90–S97. <https://doi.org/10.1097/SIH.0000000000000745>
- Goh, P.-S., & Sandars, J. (2020). A vision of the use of technology in medical education after the COVID-19 pandemic. *MedEdPublish*, 9, Article 49. <https://doi.org/10.15694/mep.2020.000049.1>
- Hou, M., Lu, Y., Liu, Y., Luo, W., Xue, H., Yuan, H., & Zhang, X. (2025). The impact of virtual reality applied in nurse education on students' clinical thinking: A systematic review. *Nurse Education Today*, 146, Article 106553. <https://doi.org/10.1016/j.nedt.2024.106553>
- Jiang, H., Vimalasvaran, S., Wang, J. K., Lim, K. B., Mogali, S. R., & Car, L. T. (2022). Virtual reality in medical students' education: Scoping review. *JMIR Medical Education*, 8(1), Article e34860. <https://doi.org/10.2196/34860>
- Keckler, M., Hsu, C. H., & Zak, P. J. (2025). Virtual reality education increases neurologic immersion and empathy in nursing students. *Nursing Reports*, 15(9), Article 336. <https://doi.org/10.3390/nursrep15090336>
- Kim, H. Y., & Kim, E. Y. (2023). Effects of medical education program using virtual reality: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, 20(5), Article 3895. <https://doi.org/10.3390/ijerph20053895>
- Kyaw, B. M., Saxena, N., Posadzki, P., Vseteckova, J., Nikolaou, C. K., George, P. P., Divakar, U., Masiello, I., Kononowicz, A. A., Zary, N., & Tudor Car, L. (2019). Virtual reality for health professions education: Systematic review and meta-analysis by the Digital Health Education Collaboration. *Journal of Medical Internet Research*, 21(1), Article e12959. <https://doi.org/10.2196/12959>
- Li, T., Yan, J., Gao, X., Liu, H., Li, J., Shang, Y., & Tang, X. (2025). Using virtual reality to enhance surgical skills and engagement in orthopedic education: Systematic review and meta-analysis. *Journal of Medical Internet Research*, 27, Article e70266. <https://doi.org/10.2196/70266>
- Lin, H. L., Wang, Y. C., Huang, M. L., et al. (2024). Can virtual reality technology be used for empathy education in medical students: A randomized case-control study. *BMC Medical Education*, 24, Article 1254. <https://doi.org/10.1186/s12909-024-06009-6>
- Liu, Y. Q. (2024). Virtual reality: The bridge between medical education and clinical practice. *World Journal of Clinical Cases*, 12(32), 6575–6579. <https://doi.org/10.12998/wjcc.v12.i32.6575>
- Marques, A. J., Gomes Veloso, P., Araújo, M., de Almeida, R. S., Correia, A., Pereira, J., Queiros, C., Pimenta, R., Pereira, A. S., & Silva, C. F. (2022). Impact of a virtual reality-based simulation on empathy and attitudes toward schizophrenia. *Frontiers in Psychology*, 13, Article 814984. <https://doi.org/10.3389/fpsyg.2022.814984>
- Minouei, M. A., Omid, A., Mirzaie, A., Mahdavi, H., & Rahimi, A. (2024). Effectiveness of virtual reality on medical students' academic achievement in anatomy: Systematic review. *BMC Medical Education*, 24, Article 1407. <https://doi.org/10.1186/s12909-024-06402-1>
- Mundok, A. G., Ho, V. N., Fowler, L. A., Kennedy, A. B., & Stark-Taylor, S. (2026). Investigating the impact of a virtual reality experience on medical student empathy: Mixed methods study. *JMIR Medical Education*, 12, Article e76504. <https://doi.org/10.2196/76504>

18. O'Connor, M., Stowe, J., Potocnik, J., Giannotti, N., Murphy, S., & Rainford, L. (2021). 3D virtual reality simulation in radiography education: The students' experience. *Radiography*, 27(1), 208–214. <https://doi.org/10.1016/j.radi.2020.07.017>
19. Pedram, S., Kennedy, G., & Sanzone, S. (2023). Toward the validation of VR-HMDs for medical education: A systematic literature review. *Virtual Reality*, 1–26. <https://doi.org/10.1007/s10055-023-00802-2>
20. Pottle, J. (2019). Virtual reality and the transformation of medical education. *Future Healthcare Journal*, 6(3), 181–185. <https://doi.org/10.7861/fhj.2019-0036>
21. Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, 147, Article 103778. <https://doi.org/10.1016/j.compedu.2019.103778>
22. Rodda, J., Mansi, H., Fernando-Sayers, J., Bennett, S., & Shergill, S. (2025). Virtual and augmented reality in undergraduate medical education in psychiatry: A systematic review. *The Clinical Teacher*, 22(4), Article e70128. <https://doi.org/10.1111/tct.70128>
23. Røe, Y., Johansen, T. S., & Bruslet, E. B. (2025). Empowering digital competence through peer-assisted learning and virtual reality in health professions education. *Frontiers in Education*, 10, Article 1550396. <https://doi.org/10.3389/feduc.2025.1550396>
24. Tay, G. W. N., Tong, M. M., Yap, J., Mak, H. K., Goh, S. Y. S., & Ho, C. S. H. (2025). Virtual reality for experiential learning: Enhancing agitation management skills, confidence, and empathy in healthcare students. *Medical Education Online*, 30(1), Article 2542809. <https://doi.org/10.1080/10872981.2025.2542809>
25. Xu, W., & Yang, X. (2025). Enhancing empathy of medical students in clinical training: A narrative-driven virtual reality experience for understanding undiagnosed chronic pain. *Frontiers in Virtual Reality*, 6, Article 1602957. <https://doi.org/10.3389/frvir.2025.1602957>
26. Yamada, R., Futakawa, K., Kondo, S., Xu, K., & Okazaki, S. (2026). A scoping review on the use of virtual patients for enhancing empathy in medical students. *Medical Education Online*, 31(1), Article 2607825. <https://doi.org/10.1080/10872981.2025.2607825>
27. Zare-Bidaki, M., Ehteshampour, A., Reisaliakbarighomi, M., Mazinani, R., Khodaie Ardakani, M. R., Mirabzadeh, A., Alikhani, R., Noroozi, M., Momeni, F., Samani, A. D., Mehrabi Tavana, M. M., Esmacili, A., & Mousavi, S. B. (2022). Evaluating the effects of experiencing virtual reality simulation of psychosis on mental illness stigma, empathy, and knowledge in medical students. *Frontiers in Psychiatry*, 13, Article 880331. <https://doi.org/10.3389/fpsy.2022.880331>
28. Zhang, W., Ding, Z., Bakaev, M., Razumnikova, O., Kludacz-Alessandri, M., & Wu, J. (2025). Immersive virtual reality based on head-mounted display in medical education: A systematic review. *BMC Medical Education*, 25(1), Article 1593. <https://doi.org/10.1186/s12909-025-08154-y>
29. Zhao, G., Fan, M., Yuan, Y., Zhao, F., & Chen, L. (2021). The comparison of teaching efficiency between virtual reality and traditional education in medical education: A systematic review and meta-analysis. *Annals of Translational Medicine*, 9(3), Article 252. <https://doi.org/10.21037/atm-20-2785>