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Samer Imad Mohammed
*Department of Clinical Pharmacy, College of Pharmacy, University of Baghdad, Baghdad, Iraq*, samer.jameel@copharm.uobaghdad.edu.iq

Mohammed Khudhair Hasan
*Department of Pharmacy. Al-Manara College for Medical Sciences. Maysan, Iraq*, dr.mohammedkhudhair@uomanara.edu.iq

Mohammad Yawuz Jamal
*Department of Clinical Pharmacy, College of Pharmacy, University of Baghdad, Baghdad, Iraq*, mohammed.ahmed@copharm.uobaghdad.edu.iq



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REVIEW

# Developing Pharmacy Education: Review of Virtual Reality Technology in Improving Clinical Training and Learning Skill Development

**Samer Imad Mohammed** [a,*], **Mohammed Khudhair Hasan** [b], **Mohammed Yawuz Jamal** [a]

[a] Department of Clinical Pharmacy, College of Pharmacy, University of Baghdad, Baghdad, Iraq
[b] Department of Pharmacy, Al-Manara College for Medical Sciences, Maysan, Iraq

## ABSTRACT

Incorporating modern technology into education is becoming imperative. Numerous pharmacy institutions are incorporating virtual reality (VR) technology training into their curricula to enhance educational experience. This review examines the current state, historical evolution, and application of VR programs in pharmacy education and training. The review also provides details about the main challenges and limitations associated with the use of this technology. The VR technology, including virtual laboratories and simulations, significantly improves clinical training and educational outcomes. The utilization of VR in clinical teaching encounters numerous barriers, including ethical concerns and technological constraints, as well as other restrictions in its execution related to these challenges. Studies suggest that VR can enhance student engagement and develop critical skills, including knowledge retention and clinical decision-making, through realistic simulations. However, outcomes may vary depending on design factors; for instance, while immersive VR environments increase presence, some evidence indicates they may not always correlate with improved learning efficiency. Despite the challenges of incorporating VR into clinical education and training, its revolutionary potential is substantial, even when accounting for the prohibitive costs and the necessity for fair access.

**Keywords:** Virtual reality (VR), Simulations, Virtual labs, Advanced technologies, Pharmacy education

## 1. Introduction

Experiential training methods are becoming more necessary in pharmacy education to address deficiencies in hands-on clinical experience. Although conventional methods encounter difficulties in simulating intricate patient interactions, VR provides a solution by utilizing safe, repeatable scenarios (Moro et al., 2017; Sharma, Singh, and Kumar, 2023).

However, adding VR to pharmaceutical activities faces a number of obstacles, such as availability and price, which require further consideration. Evaluating the present approach and possible use in pharmacy education would allow one to understand the effect of VR in the future (Kavanagh et al., 2017).

VR enables simulating complicated clinical situations in pharmacy education, which allows the students to improve their communication skills with patients and make appropriate decisions in a secure environment. As the field of education becomes more dependent on three-dimensional applications, students are allowed to interact with a virtual environment (Dalgarno and Lee, 2017).

Utilizing VR would decrease the weakness in practical learning and align with modern teaching methods to improve students' abilities. Future pharmacy

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* Corresponding author.
E-mail addresses: samer.jameel@copharm.uobaghdad.edu.iq (S. I. Mohammed), dr.mohammedkhudhair@uomanara.edu.iq (M. K. Hasan), mohammed.ahmed@copharm.uobaghdad.edu.iq (M. Y. Jamal).

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graduates can learn and improve critical cognitive and social abilities as technology evolves. This development shows the possibilities of VR to transform pharmacy education by establishing a more dynamic and engaging classroom (Barteit et al., 2021).

Practically, VR demonstrates that it can enhance health professionals' knowledge and cognitive skills after training, surpassing traditional and other digital educational methods. Notably, VR led to a marked improvement in cognitive skills and a moderate increase in knowledge (Kyaw et al., 2019).

To enhance patient safety, pharmacy institutions must equip future pharmacists with innovative, knowledgeable, and adaptable skills that allow students to develop the critical problem-solving ability necessary for pharmacy learning and realistic patient interactions (Seybert et al., 2012).

This review aims to assess the application of VR technology in pharmacy education and training by highlighting its significance, historical evolution, and global adoption trends. It provides a historical perspective, tracing VR's evolution from its inception to its current use in improving educational methods while highlighting significant occurrences that have influenced its adoption in academic settings.

## 2. Method

The authors searched prominent academic databases such as PubMed, Scopus, Science Direct, and Google Scholar to gather relevant, high-quality information. The following search terms were employed: Virtual Reality (VR), Simulations, Virtual Labs, and Advanced Technologies in Pharmacy Education. The investigation was confined to articles published in English from January 2015 to January 2025. In order to ensure a comprehensive and systematic evaluation of VR technology in clinical training and skill development, we implemented rigorous inclusion and exclusion criteria. Peer-reviewed journal articles, conference proceedings, and systematic reviews published between 2015 and 2024 were eligible studies. These studies focused on applying VR in clinical training, medical education, or healthcare skill development, such as surgical simulations and procedural training. Healthcare professionals, medical students, or trainees were the primary study population, and studies were required to report measurable outcomes such as learning efficacy, skill retention, user engagement, or cost-effectiveness. Exclusions included non-English publications (to prevent translation biases), opinion pieces, editorials, non-empirical studies lacking experimental data, studies exclusively on augmented reality (AR) or mixed reality (MR) without VR integration, and duplicate publications (retaining only the most recent or comprehensive version). The analysis was organized to first highlight the benefits of VR applications, such as simulations and virtual laboratories, in enhancing educational outcomes and examine the issues related to their execution, encompassing technical constraints and ethical implications.

## 3. Current state of VR technology in pharmacy education

Using cutting-edge technology is transforming the teaching process, and pharmacy education is a component of this transformation. A tool that is revolutionizing the game is VR, which facilitates learning through realistic simulations and direct environments. At present, VR is employed in virtual laboratories and for patient interactions, which aids students in developing their clinical skills and decision-making techniques. According to the research, students' knowledge and skill development are enhanced by their involvement with VR (Garnier et al., 2023).

However, using this technology comes with problems like inflated costs and technical difficulties that can make it hard to access. Ethical issues about using VR in education also need careful thinking. As pharmacy education advances, it is essential to investigate VR's potential for training transformation, especially with the rise of augmented reality(AR). The implementation of VR in educational environments highlights the effects of these changes (Alharbi et al., 2020).

### *3.1. Historical context of VR in education*

Technology, particularly VR, has significantly altered how we instruct. The VR was initially investigated in the late 1900s and gradually integrated into educational institutions, demonstrating its potential to augment conventional instruction. At first, it was employed in fields such as medicine, where students were trained using realistic simulations, which enhanced their engagement and helped them retain the information they had learned. For instance, interactive patient scenarios in systems enhanced students' clinical skills and established engaging learning environments (Mahmoudi-Dehaki and Nasr-Esfahani, 2004).

Now, as VR technology improves, it is also being used more in pharmacy education. This follows trends seen in other health fields by encouraging hands-on learning through virtual simulations and patient interactions. This background shows how VR has changed educational methods, leading to better learning in pharmacy training and more (Ruijia, Xuemei, and Wenling, 2024).

### 3.2. Global trends in VR adoption in pharmacy programs

Despite VR's significant potential to enhance education through immersive experiences, its implementation requires meticulous ethical analysis and preventative measures to mitigate potential adverse consequences, including diminished autonomy, health concerns, and privacy violations (Skulmowski, 2023).

The increasing utilization of VR, including virtual labs and simulations, demonstrates its potential to revolutionize pharmacy learning. Decision-makers and educators must invest in and implement these technologies while addressing cost and accessibility (Huang et al., 2019).

The global adoption of VR in pharmacy education exhibits considerable regional variation, indicative of differences in resources and infrastructure. In North America and Europe, more than 65% of leading pharmacy programs incorporate VR simulations for clinical training, supported by significant institutional investment, such as the University of Toronto's virtual dispensary lab, which serves over 800 students each year (Gharib et al., 2023).

In contrast, adoption rates in resource-limited areas such as Sub-Saharan Africa are under 15%, hindered by elevated hardware expenses and connectivity deficiencies (Agbeyangi and Suleman, 2024).

In the Asia-Pacific region, there is a notable rapid adoption of VR, as exemplified by the fact that 40% of Japanese pharmacy schools utilize VR for toxicology simulations; however, regulatory frameworks have not kept pace with this technological advancement (Tan, Faller, and Tan, 2022).

The disparities highlight the necessity for cost-adaptive models and policy interventions to guarantee equitable global access.

### 3.3. Many types of VR are being used in a wide range of learning fields

The continuous advancement of VR technologies is having a substantial impact on the field of pharmacy education. Numerous types of VR, including interactive clinical patient situations, virtual laboratories, and realistic simulations, are increasingly being implemented to facilitate pharmacy students' learning and skill development. HoloLens 2 and Oculus Rift S are two platforms that offer AR and complete immersion, respectively. These platforms enhance educational opportunities by presenting real-world scenarios that conventional methods cannot replicate. These technologies effectively enhance students' capacity to make clinical decisions and enhance their active engagement in learning clinical cases, thereby surmounting the constraints of conventional educational environments (Liu et al., 2023).

The increasing use of VR in education demonstrates its capacity to improve knowledge acquisition and equip students with the skills necessary for contemporary pharmacy practice. Its incorporation into curricula has changed pharmacy education to be at the forefront of technological innovation, greatly improving the learning process (Chen, 2016).

#### 3.3.1. Applications for VR in pharmacy education

The VR is becoming increasingly significant in pharmacy education as it improves student engagement and facilitates effective learning. This enables students to apply theoretical knowledge in practical contexts. The significance of these learning experiences in enhancing the skills required to address current healthcare demands has become increasingly evident due to the COVID-19 pandemic and the subsequent rise of remote learning (Pei and Wu, 2019). A structured summary of the primary applications of VR in clinical training, which are categorized into domains such as psychological therapy, surgical training, rehabilitation, emergency response, remote training, medical education, patient interaction, diagnostic skills, and skill assessment. Specific examples of VR implementations to improve healthcare education and practice are included in each category. Fig. 1 below shows the major technology of VR in pharmacy learning.

## 4. Simulation-based learning experiences

Simulation-based learning methods enhance students' preparedness for practical clinical challenges, improving their decision-making and problem-solving skills. Research indicates that applying simulation techniques enhances comprehension of complex pharmaceutical concepts, thereby contributing to patient safety and quality of care (Ruijia, Xuemei, and Wenling, 2024).

In particular, VR technology is becoming popular because it creates realistic patient scenarios and clinical settings, moving beyond typical teaching methods (Ahmady, Kallestrup, and Sadoughi, 2021).

The emergence of distance learning has positioned VR as a solution to the deficiencies created by events such as the COVID-19 pandemic while offering an engaging educational experience consistent with contemporary technological advancements. With the

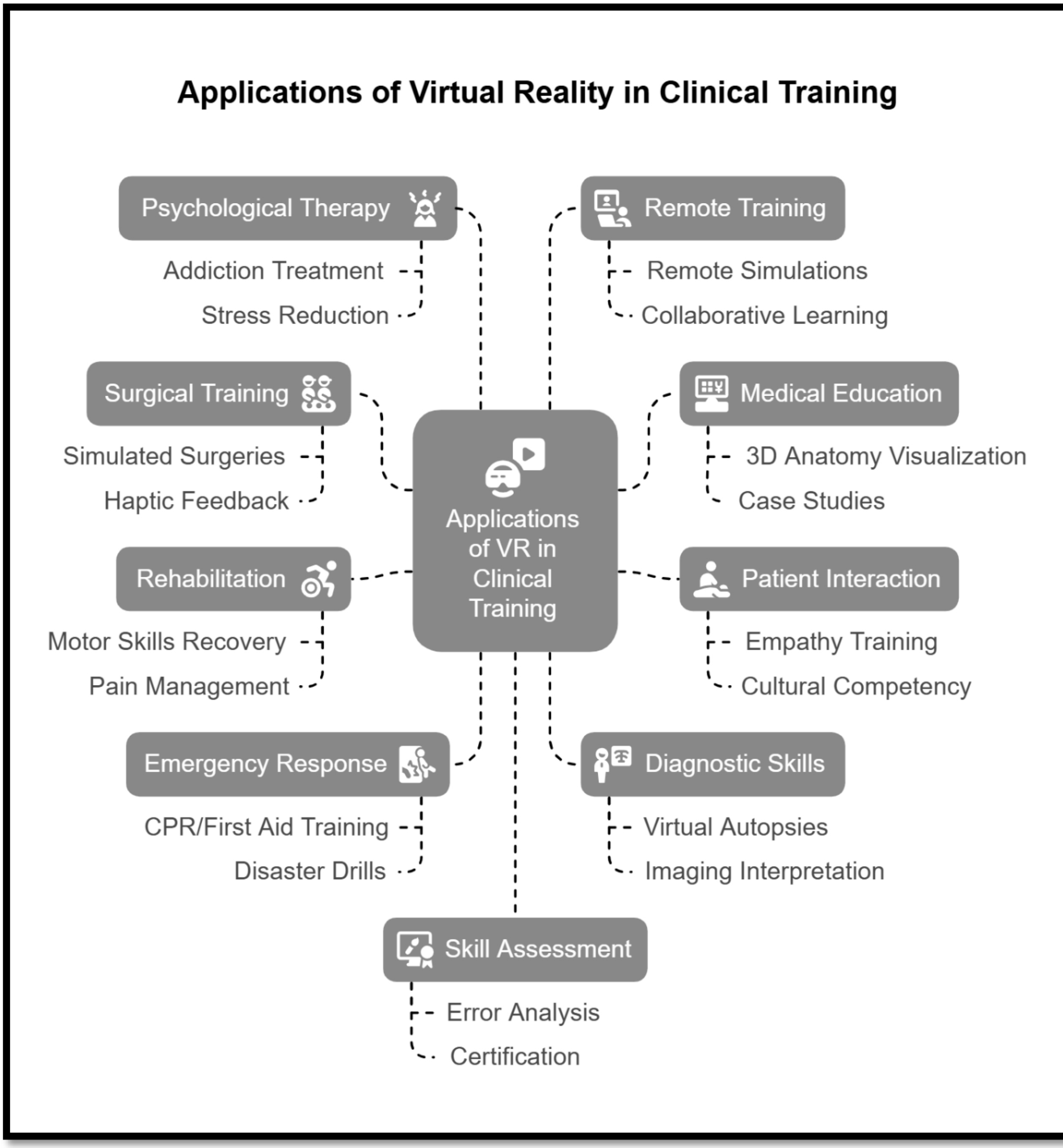


Fig. 1. Applications for VR in pharmacy education.

evolution of pharmacy programs, implementing immersive learning techniques is essential for preparing competent healthcare professionals capable of navigating a complex health landscape. The integration of these approaches will yield improved educational outcomes (Ahmady, Kallestrup, and Sadoughi, 2021).

### 4.1. Virtual laboratories for practical training

The study of new teaching methods has brought major changes in creating virtual labs for firsthand training, especially in pharmacy learning. These online labs, similar to actual lab experiences, allow students to work with complicated tools and methods without the restriction of real equipment access or safety concern (Makransky, Terkildsen, and Mayer, 2019).

A new study shows that a VR setup affects undergraduate students' understanding of High-Performance Liquid Chromatography (HPLC), and this kind of immersion greatly enhances their ability, belief, and understanding of the topic (Bin et al., 2023).

Also, AR tools can improve learning and reduce mistakes in laboratory work, indicating the need for tech-based learning. As pharmacy programs increasingly adopt these virtual labs, evaluating their teaching effectiveness and tackling drawbacks is crucial to improving learning results. The combined use of VR and AR in education can be visually represented in education models that highlight their joint use (Wu, 2024).

### 4.2. Patient interaction simulations

Immersion technology, like VR, which imitates patient cases, is becoming more useful for pharmacy students. This emulation, which is the subject of ongoing research and educational discussions, offers an optimal environment for students to develop their clinical judgment and communication skills. Enable the students to obtain practical experience and enhance teamwork (McBane et al., 2023).

In addition, the move to new teaching approaches emphasizes the demand for flexible education practices, especially during periods like the COVID-19 pandemic. Ultimately, these patient interaction simulations demonstrate the significance of VR as an important tool by helping students develop skills and prepare pharmacists for real-life issues (McBane et al., 2023).

### 4.3. Professional development and continuing education

The rapid changes in pharmacy education and the use of modern technology like VR have become more important for continuous learning and professional growth. These new approaches create new and interesting learning skills, helping the students improve their skills and knowledge about their practice (Radwan et al., 2022).

As the COVID-19 pandemic period shows, learning shifts and educational programs can adjust to the need for alternative teaching methods (Ratten, 2023).

### 4.4. Students measure their performance and evaluation

As VR technology advances, innovative methods for evaluating pharmacy students are gaining significance. VR offers a realistic environment for practice, facilitating the assessment of essential skills such as patient communication and decision-making, which are crucial in the pharmacy profession (Ruijia, Xuemei, and Wenling, 2024).

By using VR for ongoing assessments, teachers can better track how engaged students are and how they apply their knowledge, leading to better learning outcomes through quick feedback (Ratten, 2023).

Additionally, students have noted better hands-on learning, as VR can recreate clinical situations that are hard to mimic in regular classrooms, which is especially helpful when in-person training is limited (Ruijia, Xuemei, and Wenling, 2024).

#### *4.4.1. Academic effectiveness of VR in learning outcomes*

Research shows that VR makes students more involved and encourages deeper learning through active experiences that help them learn skills and make clinical choices (Liu et al., 2023).

Furthermore, VR's teaching ability is highlighted by its realistic situations, which let students apply what they learn in the classroom to real-life situations, helping to connect learning with practical use. Nevertheless, for VR to be successfully included in pharmacy education, it is important to tackle issues like cost and access so that all students have equal chances to learn (Hu-au and Lee, 2018).

### 4.5. Impact on knowledge acquisition

The VR tools help students grasp and remember tough ideas, making them more active in learning (Taylor et al., 2024).

In addition, using serious competitions in VR settings encourages more involvement and might improve skills and attitudes toward clinical work despite mixed findings on their effect on knowledge retention. Tools like videos with simulated patients have also been helpful, enhancing students' grasp of key pharmacy services (Hu-au and Lee, 2018).

### 4.6. Skill development through immersive experiences

Placing students in realistic situations can assist them in the development of skills through hands-on learning, allowing them to safely exercise complex clinical skills. This can enhance their perception and engagement (Ruijia, Xuemei, and Wenling, 2024).

In addition VR can resemble contact with patients, enabling a better appreciation of practical use and thus overcoming the shortage in equipment or clinical placements (Richardson, White, and Chapman, 2020).

### 4.7. Enhancement of clinical decision-making abilities

The VR immerses learners in immersive simulations resembling real patient scenarios, challenging students to wrestle with complex pharmacology concepts (Vázquez-Calatayud et al., 2024). Studies also show that collaborative VR learning deeply engages students and cultivates accountability during consultations. By involving each other in complex evaluations, they assume responsibility for patient outcomes similar to professional settings. This style of engaged learning sharpens critical competencies well beyond traditional classroom methods. Together, perplexing simulations and cooperative tools leverage the engaging nature of VR to train highly-skilled practitioners (Tam et al., 2024) fully.

This kind of reactive learning enables and helps students with repeated practice and immediate feedback, which is important for enhancing and developing clinical skills. Therefore, adding VR technology to the pharmacy curriculum is not only a new way of training, but it also makes an important shift in the training of pharmacists toward clinical judgment and crucial thinking (Vázquez-Calatayud et al., 2024).

### 4.8. Levels of involvement and engagement of students

Using interactive technology like VR increases pharmacy students' motivation and engagement. VR programs build their confidence and improve their competencies. When students use VR applications, they put their knowledge and what they learn into real-life clinical cases, helping them strengthen their self-esteem and polish their skills. For example, research showed that AR not only enhances students' practice but also significantly increases students' motivation to learn (Barteit et al., 2021). Additionally, practical learning provided by simulation encourages teamwork in solving clinical problems, which is very important for upcoming graduating pharmacists (Anderson et al., 2008).

#### 4.8.1. Challenges and limitations of VR implementation

There are many barriers to using VR that need to be dealt with (Ventola, 2019). It is imperative to address these obstacles to ensure VR's successful implementation in pharmacy education (Vaganova et al., 2020).

### 4.9. The cost of technology and financial limitations

Incorporating VR technology into pharmacy education imposes several financial difficulties. It limits access to important training tools in an increasingly technology-dependent education landscape (Elisandro Cabada and Ward, 2020; Mohammed et al., 2024).

Institutions face significant initial and ongoing VR hardware and software expenses, diverting funds from other essential educational priorities. Furthermore, disparities in technology budgets across institutions exacerbate inequalities in pharmacy students' access to hands-on learning experiences (Elisandro Cabada and Ward, 2020).

### 4.10. The problem of accessibility for students and institutions

Utilizing VR technology in pharmacy education has many significant challenges in accessibility for students and institutions. While VR can provide innovative educational methods. The high maintenance and purchasing cost is a substantial challenge to widespread implementation (Laurell et al., 2019).

Limited institutional resources hinder access to essential VR technology and software, which are further exacerbated by ongoing financial problems leading to pharmaceutical workforce gaps. Additionally, studies show inadequate technical assistance can impede accessibility, preventing students from fully engaging in realistic training settings (Baines et al., 2018).

### 4.11. Technical challenges and infrastructure requirements

The successful incorporation of VR technology into pharmaceutical learning necessitates addressing several critical technical and infrastructure challenges. Foremost among these is the significant cost of acquiring high-quality VR hardware and software, which can substantially limit accessibility for some institutions (Taylor et al., 2024).

Research by Barteit et al. (2021) emphasizes the significant investment required to successfully transition from conventional teaching methods to VR, including technological infrastructure and comprehensive training for faculty members on effectively using these tools. Furthermore, VR's smooth and consistent operation in educational settings is often hindered by internet speeds and software compatibility issues, requiring robust IT support and a sophisticated technological infrastructure (Barteit et al., 2021).

### 4.12. Morality in VR training

The ethical implementation of VR in pharmacy education requires proactive solutions that extend beyond theoretical frameworks. To mitigate bias, institutions should: (1) Perform mandatory algorithmic audits of VR content utilizing frameworks such as AI Fairness 360 to identify demographic disparities in clinical scenarios (DeCamp and Lindvall, 2023);

(2) Diversify training datasets through collaborations with global health networks to ensure virtual

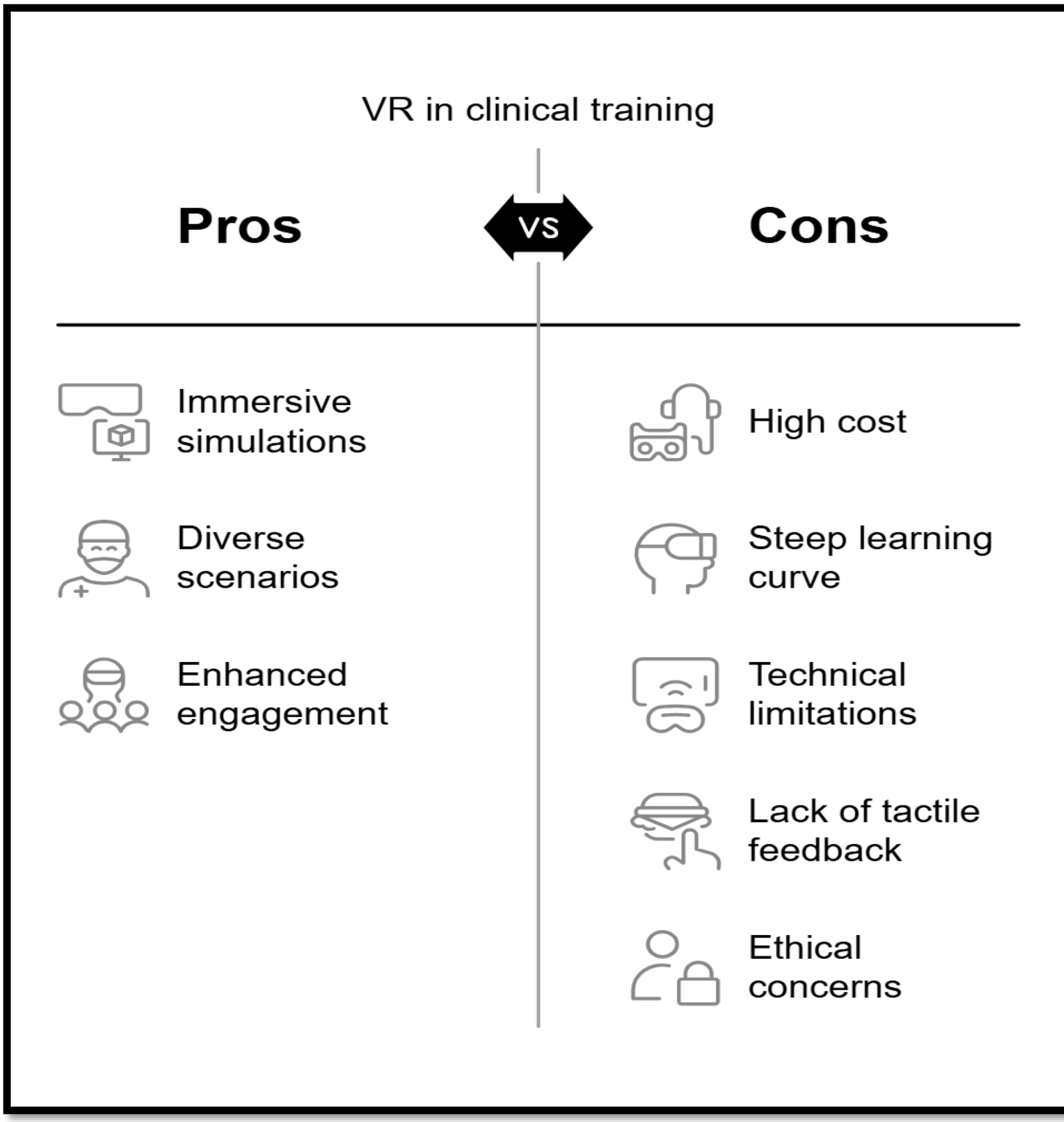


Fig. 2. Main pros and cons of using VR in clinical training.

patients represent genetic, cultural, and socioeconomic diversity (Chen et al., 2022); and (3) Establish ongoing bias monitoring where educators record and rectify skewed decision patterns (e.g., opioid prescription rates by patient ethnicity) (Hernandez-Boussard et al., 2023).

Informed consent necessitates a tiered protocol: (a) Pre-simulation disclosure of potential psychological impacts, such as cybersickness or trauma triggers in overdose scenarios; (b) Real-time opt-out mechanisms that permit students to pause or modify scenarios without academic penalty; and (c) post-session debriefing with mental health professionals following high-stress simulations. Protocols should be formalized within institutional VR ethics committees, consisting of ethicists, pharmacists, and student representatives, tasked with the annual review of consent documentation and bias reports (Tusher, Nazir, and Mallam, 2022; Bashirynejad et al., 2024).

Fig. 2 shows the main pros and cons related to the use of VR in clinical training.

## 5. Conclusion

The VR presents significant potential for pharmacy education by improving clinical decision-making, skill retention, and engagement via immersive simulations. Substantial obstacles, such as elevated costs, unequal access, technical constraints, and ethical issues, necessitate focused strategies. Educators and policymakers ought to create cost-sharing consortia and implement open-source platforms, such as Open Simulator, or affordable mobile VR options like Google Cardboard, while researchers focus on developing reusable modules. Institutions should establish device-lending programs, while policymakers ought to promote grants, such as NSF/industry partnerships, to enhance accessibility. IT departments should implement cloud-based rendering, while educators adopt hybrid models to alleviate infrastructure pressure. Ethical governance necessitates the establishment of institutional VR ethics committees to oversee privacy and consent, alongside the integration of bias training within the curriculum. Future priorities encompass longitudinal Return on Investment studies conducted by researchers, national accessibility initiatives implemented by policymakers, and faculty training programs developed by educators. Success depends on collaborative systems to provide inclusive and ethical education that addresses the changing needs of healthcare.

## Conflicts of interest

The authors declare there are no conflicts of interest.

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## Ethics statements

The Scientific and Ethical Committee of the College of Pharmacy at the University of Baghdad gave ethical approval.

## Author contribution

The authors hereby confirm their contributions to the manuscript as follows: The first author led the review conception and design. All authors conduct data collection collaboratively. Writing the review article was a joint effort involving all authors. Additionally, all authors have thoroughly reviewed and approved the last version of the manuscript before submission.

## Declaration of generative AI and AI-assisted technologies in the writing process

The Introduction, Methods, and Discussion sections of this manuscript were prepared exclusively using (QuillBot) for language refining and minor phrasing adjustments (e.g., enhancing sentence fluency or grammar). No artificial intelligence (AI) instrument was implemented for substantive writing, data analysis, or ideation; all content was originated by the authors. In order to guarantee accuracy and compliance with academic standards, the final manuscript was meticulously reviewed, edited, and approved by all authors.

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