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The Transformative Potential of Virtual Reality Technologies in Healthcare Education: Review of Efficacy in Training and Patient Education"

[1]- Salihah Hussain Mohammed Alsalem ,[2]- Hamed Ali Khder Al-Mohammadi Al-Thagafi,[3]-Yousef Mohammed Hamed Aljohani,[4]-Talal Abdulrahman Ayed Alharb.,[5]-Ali Hassan Ahmed Alnakhli,[6]- Fahad Abdulrahman Alateeq,[7]- Ali Rashed Almawash,[8]-Saad Mohammed Saad Al Mawwash,[9]-Salha Ali Amer Alshehri

[1] Ksa, Ministry Of Health, Khamis Mushait General Hospital
[2] Ksa, Ministry Of Health, Taif Center Of Endocrinology And Diabetes
[3] Ksa, Ministry Of Health, Medical Rehabilitation Hospital
[4] Ksa, Ministry Of Health, Medical Rehabilitation Hospital
[5] Ksa, Ministry Of Health, Medical Rehabilitation Hospital
[6] Ksa, Ministry Of Health, King Salman Bin Abdulaziz Hospital
[7] Ksa, Ministry Of Health, King Salman Bin Abdulaziz Hospital
[8] Ksa, Ministry Of Health, King Salman Hospital
[9] Ksa, Ministry Of Health, Muhayel General Hospital

Abstract

Background: The integration of virtual reality (VR) technologies in healthcare education has gained momentum, offering innovative approaches to enhance training for healthcare professionals. Conventional education methods often face limitations such as time constraints and a narrow range of clinical scenarios. VR presents an opportunity to overcome these challenges by providing immersive and repeatable learning experiences.

Methods: This systematic review and meta-analysis assessed the educational efficacy of VR, augmented reality (AR), and mixed reality (MR) in healthcare training. A comprehensive search of multiple databases was conducted to identify randomized controlled trials (RCTs) published from 2014 to 2023. The analysis included studies across various healthcare disciplines, focusing on knowledge acquisition, skill development, and learner attitudes.

Results: A total of 45 studies were included, revealing that VR significantly improved knowledge scores compared to traditional education methods (SMD 0.28). Notably, VR was especially effective in medical and nursing education, enhancing skill acquisition (SMD 0.23) and fostering positive attitudes toward learning (SMD 0.65). However, some studies indicated no significant differences in knowledge retention compared to conventional methods, highlighting the mixed efficacy of VR training.

Conclusion: Virtual reality technologies demonstrate substantial potential to enhance healthcare education by improving knowledge, skills, and learner satisfaction. Nonetheless, the variability in study outcomes and the need for further research on different VR modalities underscore the importance of continued investigation into the most effective applications of VR in medical training.

Keywords: Virtual reality, healthcare education, systematic review, knowledge acquisition, skill development.

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1. Introduction

The use of virtual reality (VR) in healthcare education and clinical practice has escalated in recent years [1,2]. Virtual reality-based clinical practice education seeks to enhance the clinical competencies of healthcare workers by offering them chances to use theoretical knowledge in practical healthcare environments. As a result, it has arisen as an alternative to conventional clinical practice education [3,4]. Conventional clinical education includes hospital-based clinical practice or simulations with mannequins. This educational approach is restricted by time and geographical limitations, along with a narrow range of clinical scenarios [5]. Conventional approaches are constrained by the availability of time and space for training. Moreover, the variety and thoroughness of clinical situations available to trainees are restricted. Technological educational methodologies using VR, AR, and XR have been designed as alternatives and supplements to mitigate these constraints. The debut of Hololens in 2015 and Oculus (now MetaQuest) in 2016, along with the COVID-19 epidemic, has expedited the expansion of VR-based education [6,7]. Virtual reality-based clinical practice education offers healthcare professionals the opportunity for repeated practice at any time and location, thereby allowing them to encounter a broader spectrum of authentic clinical settings [8-10].

Virtual reality-based education use computer technology to construct interactive three-dimensional environments that provide authentic experiences for students. Virtual reality (VR) may be classified into three categories: virtual reality (VR), augmented reality (AR), and mixed reality (MR) based on technology [11-14]. Virtual reality immerses the user in an entirely virtual environment, while augmented reality superimposes digital information over the actual world. Mixed Reality (MR) allows users to observe the physical environment while integrating virtual things, thereby promoting interaction between the two realms [15]. Virtual reality may be categorized into non-immersive, immersive, and semi-immersive forms. Virtual reality-based teaching includes the delivery of diverse clinical scenarios and opportunity for repeated practice [16,17]. Moreover, it offers healthcare practitioners the chance to acquire advanced skills via online learning, thereby enhancing clinical competencies [18,19]. It may improve a student's cognitive abilities and knowledge, practical and social skills and decrease mistakes [10, 20-25]. Furthermore, it may enhance a student's self-confidence, self-efficacy [28,30], and satisfaction regarding clinical knowledge and abilities [26-30]. Moreover, it entails reduced financial, ethical, and regulatory limitations and presents no danger to patients [9]. Virtual reality technology is more cost-effective than using current standardized patients or high-fidelity mannequins. It safeguards patient rights, including privacy, which is a problem linked to using real patients as training subjects [31-33]. Nonetheless, VR-based education has many drawbacks, including substantial development costs, the need for specialist equipment, and the possibility of visual fatigue for users [34]. Moreover, prior research has yielded inconsistent findings concerning the educational efficacy of virtual reality, with certain studies indicating favorable outcomes, others demonstrating no statistically significant differences, and additional studies suggesting that VR is less effective than conventional methods in terms of knowledge retention and performance metrics [10,35-38].

Numerous recent research studies have been undertaken to assess the influence of VR-based medical education in order to elucidate its educational and overall efficacy. Nonetheless, these investigations had several drawbacks. The bulk of these studies concentrated on nursing education, highlighting the need for research on the impacts of VR within a wider healthcare environment, including medicine, dentistry, and complementary and alternative medicine [4,14]. Secondly, despite the emergence of new technologies like extended reality (XR) in recent years, research has mostly concentrated on virtual reality (VR) technology [10,14,39-41]. Consequently, further research is required to assess AR, MR, and XR alongside VR. The bulk of prior research have focused on immersive or non-immersive modalities of virtual reality (VR) [39,40]. Additional research is needed to thoroughly assess its impacts across immersive, semi-immersive, and non-immersive modalities. Ultimately, scoping reviews [11] and systematic reviews [9] constituted the predominant category of investigations. Consequently, more meta-analyses are necessary to assess the educational efficacy of VR in an objective and verifiable manner.

This review sought to clarify the overall educational efficacy of virtual reality in healthcare education, addressing the limitations of previous studies and the need for more research. This study included research in healthcare disciplines (including medicine, dentistry, and nursing education) that utilized technologies (such as VR, AR, MR, and XR) in their various modalities (immersive, semi-immersive, and non-immersive) to assess the overall educational efficacy of VR. This research only used randomized controlled trials (RCTs) to thoroughly evaluate the educational efficacy of virtual reality (VR).

2. Methodology

Databases including MEDLINE (Ovid), Embase (Elsevier), Cochrane Library (Wiley), CINAHL (EBSCO), PsycINFO (EBSCO), ProQuest Central, Web of Science (Clarivate Analytics), Scopus (Elsevier), EBSCO (Academic Search Complete), and the Education Resources Information Centre (EBSCO) were queried to obtain peer-reviewed articles in the domains of medicine and education. Articles published from 2014 to 11 July 2023 were obtained using the accompanying terms and protocols:

3. Impact of Virtual Reality on Knowledge Acquisition

Beneficial outcomes were seen in medical education, nursing education, and dentistry education. Research examining the impact of augmented reality on medical education on head and neck anatomy shown that the knowledge scores of the augmented reality group surpassed those of the two-dimensional group ($p < 0.05$) [41]. Research examining the impact of virtual reality on medical education for urological disorders indicated that knowledge scores in the virtual reality group were considerably superior to those in the general practice group ($p < 0.001$) [42]. A study examining the impact of virtual reality on medical education, specifically concerning the anatomy and surgery of the esophagus and mediastinum, demonstrated that the comprehension of CT and surgical images was superior in the VR group compared to the 3D group ($p < 0.05$); however, knowledge pertaining to the mediastinal structure and general anatomy was comparable in both groups ($p > 0.05$) [43].

A study examining the impact of virtual reality on medical education concerning electrocardiograms indicated that knowledge of normal ECGs was comparable between the general lecture and VR groups ($p > 0.05$); however, knowledge of abnormal ECGs was significantly greater in the VR group ($p < 0.001$), particularly after eight weeks ($p < 0.01$) [44]. This discovery significantly contributed to the enhancement and preservation of knowledge. Research examining the impact of virtual reality on nursing education, specifically on blood transfusion, indicated that the knowledge ratings of the virtual reality group surpassed those of the Zoom lecture group ($p < 0.01$) [28]. Research examining the impact of virtual reality on nursing education on pediatric epilepsy indicated that the knowledge ratings of the virtual reality group surpassed those of the traditional lecture group ($p < 0.01$) [45]. This discovery suggests that the impact of VR may be far more beneficial than that of current instructional techniques.

Research examining the impact of virtual reality on medical education, namely in internal medicine and surgery, indicated that knowledge scores were comparable between the VR and 2D groups ($p > 0.05$); yet knowledge scores exhibited a considerable rise post-education ($p < 0.05$) [46]. This conclusion indicates that the two groups attained comparable degrees of learning, given the scenario forms and emotional involvement levels were almost equivalent. Furthermore, these findings indicate that increased immersion does not inherently result in enhanced educational outcomes, and that various cognitive processes may influence these benefits. Research examining the impact of virtual reality on medical education on postpartum hemorrhage indicated that knowledge levels in both the VR and traditional lecture groups were comparable ($p > 0.05$); yet there was a substantial increase in knowledge scores after the educational intervention ($p < 0.001$) [27]. Research examining the impact of augmented reality (AR) on medical education regarding skin disorders indicated that the effects of AR were comparable to those of mobile devices without AR ($p > 0.05$); yet knowledge scores shown a substantial rise post-education ($p > 0.05$) [47]. Research examining the impact of virtual reality on dental diagnostic and treatment education found no significant changes in the VR group for 2D and knowledge assessment (MCQ) scores ($p > 0.05$) [48].

Research examining the impact of virtual reality on medical education, specifically on internal disorders, demonstrated that assessment scores in the VR group surpassed those of the general evaluation group ($p < 0.01$). This discovery demonstrates that the use of VR enhances thinking and therapeutic competencies via realistic simulations [46]. The results of the aforementioned research demonstrate that the use of VR produced impacts comparable to traditional teaching approaches, irrespective of whether the outcomes in the experimental group were positive or statistically insignificant. A notable enhancement after instruction was seen in both the experimental and control groups. This conclusion suggests that both instructional approaches were beneficial; hence, it is advantageous to integrate the two ways based on the objective. Moreover, the research assessing the impact of VR on nursing education related to perinatal illness revealed no significant changes in knowledge scores between VR and high-fidelity mannequin simulation instruction ($p > 0.05$) [26]. High-fidelity simulation is costly due to its need for substantial labor and equipment. Conversely, VR is comparatively affordable and secure, enables unrestricted repeating learning, and yields analogous educational outcomes; hence, its use in education is practical.

Research examining the impact of virtual reality on medical education, specifically on lumbar puncture, indicated that the oral examination scores of the virtual reality group were significantly lower than those of the traditional education group ($p < 0.001$) [47]. Research examining the impact of virtual reality on nurse education regarding tracheal suction indicated that knowledge levels were comparable across the 2D, low-level VR, and high-level VR groups ($p > 0.05$); yet the scores improved after the educational intervention. The results in the 2D group surpassed those in the VR-low group ($p < 0.05$), but the scores in the 2D and VR-high groups were comparable ($p > 0.05$) [48]. This research indicates that VR and 2D education provide comparable outcomes, or that 2D education may be more effective, maybe due to discomfort, unfamiliarity, and less focus associated with VR-based teaching. Prior research has shown that virtual reality enhances clinical proficiency [49-52].

Furthermore, it facilitates information acquisition by fostering self-directed learning and encouraging active engagement [53]. Prior research has shown that immersive VR learning may impart more information than non-immersive strategies [54]. Virtual reality offers visual, aural, and diverse stimuli; delivers rapid feedback to learners via real-time engagement; and enhances information retention by fostering three-dimensional creativity, active manipulation, and the development of learning abilities. It also cultivates a pleasurable and appealing educational atmosphere that stimulates attention and curiosity [55-57]. Moreover, the volume of learning escalates with heightened student happiness, whereas discontent diminishes in tandem with improved academic success [58]. Augmented Reality (AR) generates an immersive setting using a three-dimensional framework, allowing anatomical and virtual worlds to coexist and interact simultaneously, therefore augmenting knowledge and comprehension [59]. Consequently, virtual reality may enhance the understanding of medical practitioners via several avenues.

4. Impact of Virtual Reality on Skill Development

Research examining the impact of virtual reality on medical education, specifically on ultrasound, indicated that the OSAUS score for the VR group surpassed that of the e-learning group ($p < 0.01$). Despite the hand-eye score being elevated, it lacked statistical significance ($p > 0.05$) [60]. Research examining the impact of virtual reality on medical education related to dizziness shown that VR-standardized patients achieved superior competence ratings compared to regular standardized patients ($p < 0.05$) [50]. Research examining the impact of virtual reality on medical education on myocardial infarction shown that the OSCE scores and EKG/thrombolysis performance times in the virtual reality group were comparable to those in the discussion courses group ($p > 0.05$) [57]. This may be ascribed to the benefits linked to discussion courses (control group), including engagement, retention and enhancement of information and skills, collaborative abilities, and autonomous learning [61-63]. Furthermore, the instruction was given either once or for a little duration. Therefore, more growth and sustained education are necessary in the future.

Research examining the impact of virtual reality on medical education concerning perinatal disorders indicated that skill ratings in both the VR and traditional lecture groups were comparable ($p > 0.05$); yet the time taken for skill performance was significantly reduced ($p < 0.05$) [27]. This discovery demonstrates that VR is efficacious in decreasing performance duration. Research examining the impact of virtual reality on medical education about lumbar puncture indicated that skill ratings in both the VR and traditional lecture groups were comparable ($p > 0.05$); yet the duration of skill performance was significantly reduced

($p < 0.01$) [63]. Research on medical education about bladder catheters indicated that the OSCE scores of the MR education group surpassed those of the face-to-face training group ($p < 0.01$) [22]. Research examining the impact of augmented reality on nurse education regarding IV catheters indicated that the skill scores (IVC–PPSF) in the augmented reality group surpassed those of the simulator education group ($p < 0.05$); nevertheless, the skill times were comparable ($p > 0.05$) [64]. Research examining the impact of augmented reality on medical education, specifically in history taking, indicated that the skill scores (DOPS) in the augmented reality group above those in the traditional simulator group ($p < 0.05$); however, the skill scores (Mini-CEX) for other competencies were comparable ($p > 0.05$) [21]. This may be ascribed to the elevated cognitive load hindering learning performance when the intrinsic cognitive load escalates in the VR group [65]. Moreover, VR newbies may have challenges in using the Mini-CEX, and the assessment results may be comparable due to the inherent features of the Mini-CEX. Therefore, a design that regulates intrinsic cognitive load while attaining optimal educational outcomes must be used in program development.

A study of the impacts of structured vs non-structured briefings on VR-based surgical nurse education indicated that the competence scores were comparable ($p < 0.05$) [66]. A comparison of the OSCE results across the 2D, VR-low, and VR-high groups in research examining the impact of VR on nursing education on tracheal suction indicated that the scores of the 2D group surpassed those of the VR-low and VR-high groups [67]. This observation may be ascribed to 70% of students lacking familiarity with VR treatments, resulting in their emphasis on procedural learning. In contrast to 2D video-based methods that display actual catheters or gloves, VR-based methods provide abstract objects, resulting in less accuracy. The multifunctionality of VR, particularly with simulation emphasis or interaction quality, may result in cognitive overload. Likewise, the haptic function may be cumbersome due to its lack of intuitiveness, perhaps leading to user frustration. Consequently, including skills training with actual mannequins into forthcoming VR-based teaching will provide superior outcomes. Research examining the impact of virtual reality on nursing education, specifically on pediatric examinations, indicated that the competence scores of the virtual reality group surpassed those of the conventional education group ($p > 0.001$) [65]. Research examining the impact of VR on nursing education regarding IV catheters indicated that the competence scores in the VR group surpassed those in the practice model group ($p < 0.01$) [68]. Research examining the impact of VR on dental diagnosis and treatment indicated that the skill scores of the VR group surpassed those of the control group in the first practice scenario ($p < 0.05$); however, no significant changes were seen in the subsequent situations ($p > 0.05$) [69]. The experimental group had a comparable or superior capacity to enhance clinical abilities relative to the control group. Consequently, virtual reality enhances psychomotor abilities by promoting multisensory learning and enabling repeated practice without spatial and temporal limitations [70].

VR surgical simulators enhance surgical abilities due to their minimal setup time and repeatability [71]. Immersive VR-based instruction allows learners to execute clinical methods, such as anesthesia, with more precision and confidence [72]. This method allows learners to repeatedly practice procedure stages until they gain confidence, hence minimizing the risk of patient damage throughout the process [73]. While excluded from the meta-analysis, the skill score (CSA) in the VR group surpassed that of the general education group in six out of eleven instances ($p < 0.05$) in a BLS medical education research; also, the no flow time was extended ($p < 0.001$) [53]. The VR group exhibited a reduced no flow time ($p < 0.01$), diminished performance penalty ($p < 0.001$), and elevated skill scores (CSAs) in five out of eleven instances ($p < 0.001$) in alternative BLS education research [59].

A study of the impacts of a 2-week vs a 4-week VR-based educational program in emergency medicine shown that the OSCE scores were comparable ($p > 0.05$) but significantly elevated in the 4-week group ($p < 0.05$) [55]. Research examining the impact of virtual reality on nurse education in catastrophe scenarios indicated that, relative to mannequin-based training, virtual reality enhanced knowledge, abilities, and confidence ($p < 0.01$) [74]. This pedagogical approach leverages the optimal benefits of VR technology, facilitating learning in a secure and regulated environment while honing skills via the simulation of scenarios that are impractical to replicate, such as crises and disasters [75].

5. Impact of Virtual Reality on Attitudes

This discovery suggests that VR positively influences learning attitudes. Research examining the impact of virtual reality on medical education for patients with dizziness indicated that VR-standardized patients had comparable pleasure and sensation of presence to traditional standardized patients ($p > 0.05$) [50]. Research examining the impact of augmented reality on nurse education regarding IV catheters indicated that augmented reality and simulator-based teaching produced comparable satisfaction and confidence levels ($p > 0.05$) [68]. Research examining the impact of virtual reality on medical education about postpartum hemorrhage indicated that virtual reality and traditional lectures produced comparable satisfaction and confidence levels ($p > 0.05$) [27].

Research examining the impact of virtual reality on nursing education related to transfusion indicated that satisfaction and confidence levels in the VR group surpassed those in the Zoom lecture group ($p < 0.05$), while self-efficacy was elevated but not statistically significant ($p > 0.05$) [28]. Confidence is the conviction that a certain expectation may be realized, whereas self-efficacy is the assessment of one's capability to execute required tasks. The experimental group acquired more knowledge and confidence; yet no significant changes were noted about their performance in a real-world setting. Consequently, virtual reality must be engineered to enhance practicality and educational outcomes in forthcoming research [28]. Research examining the impact of virtual reality on nurse education about tracheal suction indicated that satisfaction levels ranked as follows: VR-low, VR-high, and 2D video ($p < 0.001$) [74]. The virtual reality experience was authentic, engaging, and enveloping. Moreover, it allowed healthcare professionals to hone their abilities in a secure setting, learn from errors, and enhance their knowledge and confidence. The simpler VR-low exhibited elevated satisfaction levels; hence, complicated functionalities that induce undue cognitive load should be eschewed in the development of a VR program. Research examining the impact of virtual reality on nursing education, specifically in pediatric examination, indicated that satisfaction and confidence levels in the virtual reality group surpassed those in the traditional lecture group ($p < 0.001$) [29].

Research examining the impact of VR on dental imaging shown that the learning satisfaction and self-efficacy levels in the VR group surpassed those in the 2D video group ($p < 0.01$) [30]. A study examining the impact of VR on nursing education, specifically in perinatal nursing, indicated that the anxiety and confidence levels of participants in the VR group surpassed those of the mannequin simulation group ($p < 0.01$); however, this difference was not statistically significant ($p > 0.05$) [26]. This data suggests that confidence levels were elevated in both groups; nevertheless, a significant increase in worry may have arisen from the VR technology itself. Prior research indicates that teacher assistance, mentorship from senior peers, and orientation on the surroundings and simulation help alleviate anxiety [76]. Consequently, VR simulation can significantly impact learners' attitudes by providing a realistic and secure environment for practice, facilitating knowledge acquisition, enhancing clinical performance, critical thinking, and decision-making, as well as boosting confidence and communication skills [26]. While not part of the study synthesis, prior studies indicate that VR-based education is generally well-received regarding program acceptance and overall assessment; yet there were instances when face-to-face simulation was favored. This may be ascribed to technological factors. Therefore, it is essential to configure it in a straightforward and accessible manner to enable pupils to focus without getting disoriented.

Research examining the impact of VR on medical education, particularly on internal and surgical disorders, demonstrated that the VR group outperformed the 2D group in four out of eleven experiential assessments ($p < 0.05$). External alterations were more evident in the 2D group; nevertheless, a greater prevalence was seen in the VR group [47]. Significant engagement and favorable feedback were noted in the VR group. Consequently, it may be appropriate to create a 3D model that is more conducive to group-based simulation and a 2D format as a self-directed learning resource using familiar home equipment.

6. Constraints

This research covered publications with RCTs published in English, albeit its scope may be restricted. This research analyzed several VR technologies; nonetheless, notable discrepancies were identified even among the same VR and AR technologies, contingent upon the kind of HMDs and the complexity of the programs used. The significant heterogeneity among the studies hindered the execution of the meta-analysis. The study designs of the included research varied, as did the instructional content, duration, and timeframe of the intervention group. Heterogeneity was also noted within the control groups of several experiments, including traditional face-to-face lectures, Zoom lectures, e-learning, high-fidelity and low-fidelity simulations, and two-dimensional graphics. The study population included students and locals. Students may exhibit heterogeneity about their knowledge and abilities within each grade.

7. Conclusions

This comprehensive literature review and meta-analysis of randomized controlled trials sought to evaluate the importance of virtual reality in healthcare education. An analysis of the 45 selected studies indicated that the implementation of virtual reality (VR) resulted in a notable enhancement in knowledge and skill scores, reduced skill performance time, and increased satisfaction and confidence levels. This study's results demonstrate that VR may significantly improve learning outcomes while alleviating logistical obstacles, including personnel, time, space, and cost, often linked to conventional training techniques.

Based on the review of previous studies, the following recommendations are given for future research: First, future studies should use educational theories and frameworks with objective assessment instruments. Secondly, research including long-term education with a substantial participant base is essential. Third, it is essential to design VR simulations that leverage cooperation among users in the virtual environment. In the next years, VR technology will be increasingly used in healthcare education, including more realistic and user-friendly simulations. Virtual reality-based education will enhance self-directed learning by offering immersive, interactive experiences and instant feedback. This strategy may be particularly useful in combining VR with conventional teaching techniques, since it improves the quality of learning and the overall proficiency of healthcare workers.

References

[1] Gao, S.; He, T.; Zhang, Z.; Ao, H.; Jiang, H.; Lee, C. A motion capturing and energy harvesting hybridized lower-limb system for rehabilitation and sports applications. Adv. Sci. 2021, 8, e2101834.

[2] Rojas-Sanchez, M.A.; Palos-Sanchez, P.R.; Folgado-Fernandez, J.A. Systematic Literature Review and Bibliometric Analysis on Virtual Reality and Education. Educ. Inf. Technol. 2022, 28, 155–192.

[3] Jiang Z, Wu H, Cheng H, Wang W, Xie AN, Fitzgerald SR. Twelve tips for teaching medical students online under COVID-19. Medical education online. 2021 Jan 1;26(1):1854066.

[4] Liu JY, Yin YH, Kor PP, Cheung DS, Zhao IY, Wang S, Su JJ, Christensen M, Tyrovolas S, Leung AY. The effects of immersive virtual reality applications on enhancing the learning outcomes of undergraduate health care students: systematic review with meta-synthesis. Journal of Medical Internet Research. 2023 Mar 6;25:e39989.

[5] Hall, J.P.; Allman, S.A. Blending virtual reality with traditional approaches to encourage engagement with core chemistry concepts relevant to an undergraduate pharmacy curriculum. Pharm. Educ. 2020, 20, 365–374. [Google Scholar] [CrossRef]

[6] Han, E.R.; Yeo, S.; Kim, M.J.; Lee, Y.H.; Park, K.H.; Roh, H. Medical education trends for future physicians in the era of advanced technology and artificial intelligence: An integrative review. BMC Med. Educ. 2019, 19, 460.

[7] Jensen, L.X.; Buhl, A.; Hussain, S.; Karan, A.; Konradsen, F.; Bearman, M. Digital education for health professionals in India: A scoping review of the research. BMC Med. Educ. 2023, 23, 561.

[8] Jiang, H.; Vimalesvaran, S.; Wang, J.K.; Lim, K.B.; Mogali, S.R.; Car, L.T. Virtual reality in medical students' education: Scoping review. JMIR Med. Educ. 2022, 8, e34860.

[9] Barteit, S.; Lanfermann, L.; Bärnighausen, T.; Neuhann, F.; Beiersmann, C. Augmented, mixed, and virtual reality-based head-mounted devices for medical education: Systematic review. JMIR Serious Games 2021, 9, e29080.

[10] Chen, F.Q.; Leng, Y.F.; Ge, J.F.; Wang, D.W.; Li, C.; Chen, B.; Sun, Z.L. Effectiveness of virtual reality in nursing education: Meta-analysis. J. Med. Internet Res. 2020, 22, e18290.
[11] Miltykh, I.; Kafarov, E.S.; Covantsev, S.; Dadashev, A.S.; Skarlis, A.A.; Zenin, O.K. A new dimension in medical education: Virtual reality in anatomy during COVID-19 pandemic. Clin. Anat. 2023, 36, 24098.
[12] Shorey S, Ng ED. The use of virtual reality simulation among nursing students and registered nurses: A systematic review. Nurse education today. 2021 Mar 1;98:104662.
[13] Camargo-Vargas, D.; Callejas-Cuervo, M.; Mazzoleni, S. Brain-computer interfaces systems for upper and lower limb rehabilitation: A systematic review. Sensors 2021, 21, 4312.
[14] Jallad ST, Işık B. The effectiveness of virtual reality simulation as learning strategy in the acquisition of medical skills in nursing education: a systematic review. Irish Journal of Medical Science (1971-). 2021 Jul 5:1-20.
[15] Zagury-Orly, I.; Solinski, M.A.; Nguyen, L.H.; Young, M.; Drozdowski, V.; Bain, P.A.; Gantwerker, E.A. What is the current state of extended reality use in otolaryngology training? A scoping review. Laryngoscope 2023, 133, 227–234.
[16] Plotzky, C.; Lindwedel, U.; Sorber, M.; Loessl, B.; König, P.; Kunze, C.; Kugler, C.; Meng, M. Virtual reality simulations in nurse education: A systematic mapping review. Nurse Educ. Today 2021, 101, 104868.
[17] Shorey, S.; Ng, E.D. The use of virtual reality simulation among nursing students and registered nurses: A systematic review. Nurse Educ. Today 2021, 98, 104662.
[18] Treat, C.; Maniker, R.; Kessler, D. 182 All clear! Virtual reality defibrillator training for medical students is feasible, liked, and improves perceived knowledge, comfort, and skills. Ann. Emerg. Med. 2022, 80, S83.
[19] Jeong, Y.; Lee, H.; Han, J.W. Development and evaluation of virtual reality simulation education based on coronavirus disease 2019 scenario for nursing students: A pilot study. Nurs. Open 2022, 9, 1066–1076.
[20] Chao, Y.P.; Chuang, H.H.; Hsin, L.J.; Kang, C.J.; Fang, T.J.; Li, H.Y.; Lee, L.A. Using a 360 virtual reality or 2D video to learn history taking and physical examination skills for undergraduate medical students: Pilot randomized controlled trial. JMIR Serious Games 2021, 9, e13124.
[21] Chao, Y.P.; Kang, C.J.; Chuang, H.H.; Hsieh, M.J.; Chang, Y.C.; Kuo, T.B.J.; Yang, C.C.H.; Huang, C.G.; Fang, T.J.; Li, H.Y.; et al. Comparison of the effect of 360 versus two-dimensional virtual reality video on history taking and physical examination skills learning among undergraduate medical students: A randomized controlled trial. Virtual Real. 2023, 27, 637–650.
[22] Schoeb, D.S.; Schwarz, J.; Hein, S.; Schlager, D.; Pohlmann, P.F.; Frankenschmidt, A.; Miernik, A. Mixed reality for teaching catheter placement to medical students: A randomized single-blinded, prospective trial. BMC Med. Educ. 2020, 20, 510.
[23] Ammanuel, S.; Brown, I.; Uribe, J.; Rehani, B. Creating 3D models from radiologic images for virtual reality medical education modules. J. Med. Syst. 2019, 43, 166.
[24] Klimova, A.; Bilyatdinova, A.; Karsakov, A. Existing teaching practices in augmented reality. Procedia Comput. Sci. 2018, 136, 5–15.
[25] Piromchai, P.; Avery, A.; Laopaiboon, M.; Kennedy, G.; O'Leary, S. Virtual reality training for improving the skills needed for performing surgery of the ear, nose or throat. Cochrane Database Syst. Rev. 2015, 9, CD010198.
[26] Cobbett, S.; Snelgrove-Clarke, E. Virtual versus face-to-face clinical simulation in relation to student knowledge, anxiety, and self-confidence in maternal-newborn nursing: A randomized controlled trial. Nurse Educ. Today 2016, 45, 179–184.
[27] Voillequin S, Rozenberg P, Letutour K, Rousseau A. Comparative satisfaction and effectiveness of virtual simulation and usual supervised work for postpartum hemorrhage management: a crossover randomized controlled trial. BMC medical education. 2022 Oct 6;22(1):709.

[28] Lee, J.J.; Tsang, V.W.Y.; Chan, M.M.K.; O'Connor, S.; Lokmic-Tomkins, Z.; Ye, F.; Kwok, J.Y.Y.; Ho, M.H. Virtual reality simulation-enhanced blood transfusion education focusing on undergraduate nursing students: A randomised controlled trial. Nurse Educ. Today 2023, 129, 105903.
[29] Cura ŞÜ, Kocatepe V, Yıldırım D, Küçükakgün H, Atay S, Ünver V. Examining knowledge, skill, stress, satisfaction, and self-confidence levels of nursing students in three different simulation modalities. Asian nursing research. 2020 Aug 1;14(3):158-64.
[30] Lim, J.E.; Gu, J.Y.; Bae, J.H.; Lee, J.G. Comparative study of 360° virtual reality and traditional two-dimensional video in nonface-to-face dental radiology classes: Focusing on learning satisfaction and self-efficacy. BMC Med. Educ. 2023, 23, 855.
[31] Rosen, K.R. The history of medical simulation. J. Crit. Care 2008, 23, 157–166.
[32] Watterson, L.; Flanagan, B.; Donovan, B.; Robinson, B. Anaesthetic simulators: Training for the broader health-care profession. Aust. N. Z. J. Surg. 2000, 70, 735–737.
[33] Ellis, C.; Hughes, G. Use of human patient simulation to teach emergency medicine trainees advanced airway skills. J. Accid. Emerg. Med. 1999, 16, 395–399.
[34] Jensen, L.; Konradsen, F. A review of the use of virtual reality head-mounted displays in education and training. Educ. Inf. Technol. 2018, 23, 1515–1529.
[35] Hwang, G.J.; Chang, C.Y.; Ogata, H. The effectiveness of the virtual patient-based social learning approach in undergraduate nursing education: A quasi-experimental study. Nurse Educ. Today 2022, 108, 105164.
[36] Sarvan, S.; Efe, E. The effect of neonatal resuscitation training based on a serious game simulation method on nursing students' knowledge, skills, satisfaction and self-confidence levels: A randomized controlled trial. Nurse Educ. Today 2022, 111, 105298.
[37] Bryant, R.; Miller, C.L.; Henderson, D. Virtual clinical simulations in an online advanced health appraisal course. Clin. Simul. Nurs. 2015, 11, 437–444.
[38] Farra, S.L.; Smith, S.; Gillespie, G.L.; Nicely, S.; Ulrich, D.L.; Hodgson, E.; French, D. Decontamination training: With and without virtual reality simulation. Adv. Emerg. Nurs. J. 2015, 37, 125–133. [Google Scholar] [CrossRef] [PubMed]
[39] Cao, Y.; Ng, G.W.; Ye, S.S. Design and evaluation for immersive virtual reality learning environment: A systematic literature review. Sustainability 2023, 15, 1964.
[40] Qiao, J.; Huang, C.R.; Liu, Q.; Li, S.Y.; Xu, J.; Li, L.; Redding, S.R.; Ouyang, Y.Q. Effectiveness of non-immersive virtual reality simulation in learning knowledge and skills for nursing students: Meta-analysis. Clin. Simul. Nurs. 2023, 76, 26–38.
[41] Kim, H.-Y.; Kim, E.-Y. Effects of Medical Education Program Using Virtual Reality: A Systematic Review and Meta-Analysis. Int. J. Environ. Res. Public Health 2023, 20, 3895.
[42] Higgins, J.; Thomas, J.; Chandler, J.; Cumpston, M.; Li, T.; Page, M.; Welch, V. Cochrane Handbook for Systematic Reviews of Interventions; John Wiley & Sons: Hoboken, NJ, USA, 2019.
[43] Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA statement. PLOS Med. 2009, 6, e1000097.
[44] Amir-Behghadami, M.; Janati, A. Population, Intervention, Comparison, Outcomes and Study (PICOS) design as a framework to formulate eligibility criteria in systematic reviews. Emerg. Med. J. 2020, 37, 387.
[45] Bloom, B.S. Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain; David McKay Company: New York, NY, USA, 1956.
[46] Abreu, J.M.; Guimarães, B.; Castelo-Branco, M. The role of virtual interactive simulators in medical education: Exploring their integration as an assessment methodology in clinical years. Educ. Med. 2021, 22, 325–329.
[47] Bray, L.; Spencer, S.; Pearson, E.; Meznikova, K.; Hepburn, D. Assessing the impact of immersion on learning in medical students: A pilot study comparing two-dimensional and three-dimensional virtual simulation. Simul. Gaming 2023, 54, 576–592.

[48] Ekstrand, C.; Jamal, A.; Nguyen, R.; Kudryk, A.; Mann, J.; Mendez, I. Immersive and interactive virtual reality to improve learning and retention of neuroanatomy in medical students: A randomized controlled study. CMAJ Open 2018, 6, E103–E109.
[49] Gan, W.; Mok, T.N.; Chen, J.; She, G.; Zha, Z.; Wang, H.; Li, H.; Li, J.; Zheng, X. Researching the application of virtual reality in medical education: One-year follow-up of a randomized trial. BMC Med. Educ. 2023, 23, 3.
[50] Han, S.G.; Kim, Y.D.; Kong, T.Y.; Cho, J. Virtual reality-based neurological examination teaching tool(VRNET) versus standardized patient in teaching neurological examinations for the medical students: A randomized, single-blind study. BMC Med. Educ. 2021, 21, 493.
[51] Imai, T.; Tanaka, Y.; Hatanaka, Y.; Suetsugu, T.; Sato, Y.; Matsuhashi, N.; Tsunekawa, K.; Saiki, T.; Yoshida, K. Incorporation of virtual reality in the clinical training of medical students studying esophageal and mediastinal anatomy and surgery. Surg. Today 2022, 52, 1212–1217.
[52] Chang CY, Kao CH, Hwang GJ, Lin FH. From experiencing to critical thinking: a contextual game-based learning approach to improving nursing students' performance in electrocardiogram training. Educational Technology Research and Development. 2020 Jun;68:1225-45.
[53] Issleib, M.; Kromer, A.; Pinnschmidt, H.O.; Süss-Havemann, C.; Kubitz, J.C. Virtual reality as a teaching method for resuscitation training in undergraduate first year medical students: A randomized controlled trial. Scand. J. Trauma Resusc. Emerg. Med. 2021, 29, 27.
[54] Sun P, Zhao Y, Men J, Ma ZR, Jiang HZ, Liu CY, Feng W. Application of virtual and augmented reality technology in hip surgery: systematic review. Journal of Medical Internet Research. 2023 Mar 10;25:e37599.
[55] Law, A.K.K.; Hung, K.K.C.; James, K.S.; Kelly, A.M.; Graham, C.A. Virtual patient simulation in undergraduate emergency medicine education during COVID-19: Randomized controlled trial. Hong Kong J. Emerg. Med. 2023, 30, 439–446.
[56] Lebdai, S.; Mauget, M.; Cousseau, P.; Granry, J.C.; Martin, L. Improving academic performance in medical students using immersive virtual patient simulation: A randomized controlled trial. J. Surg. Educ. 2021, 78, 478–484.
[57] Martinez, F.T.; Soto, J.P.; Valenzuela, D.; González, N.; Corsi, J.; Sepúlveda, P. Virtual clinical simulation for training amongst undergraduate medical students: A pilot randomised trial (VIRTUE-pilot). Cureus 2023, 15, e47527.
[58] McGrath, J.; Kman, N.; Danforth, D.; Bahner, D.P.; Khandelwal, S.; Martin, D.R.; Nagel, R.; Verbeck, N.; Way, D.P.; Nelson, R. Virtual alternative to the oral examination for emergency medicine residents. West. J. Emerg. Med. 2015, 16, 336–343.
[59] Moll-Khosrawi, P.; Falb, A.; Pinnschmidt, H.; Zöllner, C.; Issleib, M. Virtual reality as a teaching method for resuscitation training in undergraduate first year medical students during COVID-19 pandemic: A randomised controlled trial. BMC Med. Educ. 2022, 22, 483.
[60] Moro, C.; Phelps, C.; Redmond, P.; Stromberga, Z. HoloLens and mobile augmented reality in medical and health science education: A randomised controlled trial. Brit. J. Educ. Tech. 2021, 52, 680–694.
[61] Nielsen, M.R.; Kristensen, E.Q.; Jensen, R.O.; Mollerup, A.M.; Pfeiffer, T.; Graumann, O. Clinical ultrasound education for medical students: Virtual reality versus e-learning, a randomized controlled pilot trial. Ultrasound Q. 2021, 37, 292–296.
[62] Noll, C.; von Jan, U.; Raap, U.; Albrecht, U.V. Mobile augmented reality as a feature for self-oriented, blended learning in medicine: Randomized controlled trial. JMIR MHealth UHealth 2017, 5, e139.
[63] Ros, M.; Neuwirth, L.S.; Ng, S.; Debien, B.; Molinari, N.; Gatto, F.; Lonjon, N. The effects of an immersive virtual reality application in first person point-of-view (IVRA-FPV) on the learning and generalized performance of a lumbar puncture medical procedure. Educ. Technol. Res. Dev. 2021, 69, 1529–1556.
[64] Arif A, Felipes RC, Hoxhaj M, Light MB, Dadario NB, Cook B, Cataldo MJ, Jafri FN. The impact of the addition of a virtual reality trainer on skill retention of tourniquet application for hemorrhage control among emergency medical technician students: a pilot study. Cureus. 2023 Jan;15(1).

[65] Shah, N.K.; Taunk, N.K.; Maxwell, R.; Wang, X.; Hubley, E.; Anamalayil, S.; Li, T. Comparison of virtual reality platforms to enhance medical education focusing on procedures. Front. Virtual Real. 2022, 3, 1000035.
[66] Weeks, J.K.; Pakpoor, J.; Park, B.J.; Robinson, N.J.; Rubinstein, N.A.; Prouty, S.M.; Nachiappan, A.C. Harnessing augmented reality and CT to teach first-year medical students head and neck anatomy. Acad. Radiol. 2021, 28, 871–876.
[67] Zackoff, M.W.; Real, F.J.; Sahay, R.D.; Fei, L.; Guiot, A.; Lehmann, C.; Tegtmeyer, K.; Klein, M. Impact of an immersive virtual reality curriculum on medical students' clinical assessment of infants with respiratory distress. Pediatr. Crit. Care Med. 2020, 21, 477–485.
[68] Rochlen LR, Putnam E, Levine R, Tait AR. Mixed reality simulation for peripheral intravenous catheter placement training. BMC Medical Education. 2022 Dec 17;22(1):876.
[69] Rad RF, Sadrabad AZ, Nouraei R, Khatony A, Bashiri H, Bozorgomid A, Rezaeian S. Comparative study of virtual and face-to-face training methods on the quality of healthcare services provided by Kermanshah pre-hospital emergency staff (EMS): randomized educational Intervention trial. BMC medical education. 2022 Mar 25;22(1):203.
[70] Wells T, Miller G. The effect of virtual reality technology on welding skill performance. Journal of Agricultural Education. 2020 Mar 28;61(1):152-71.
[71] Fung, J.T.C.; Chan, S.L.; Takemura, N.; Chiu, H.Y.; Huang, H.C.; Lee, J.E.; Preechawong, S.; Hyun, M.Y.; Sun, M.; Xia, W.; et al. Virtual simulation and problem-based learning enhance perceived clinical and cultural competence of nursing students in Asia: A randomized controlled cross-over study. Nurse Educ. Today 2023, 123, 105721.
[72] Padilha, J.M.; Machado, P.P.; Ribeiro, A.L.; Ramos, J.L. Clinical virtual simulation in nursing education. Clin. Simul. Nurs. 2018, 15, 13–18.
[73] Penalo, L.M. Effect of the Virtual simulation prebriefing-debriefing educational strategy on nursing students' self-efficacy and performance concerning the care of patients experiencing a myocardial infarction: A quasi-experimental study. Clin. Simul. Nurs. 2023, 82, 101431.
[74] Plotzky, C.; Loessl, B.; Kuhnert, B.; Friedrich, N.; Kugler, C.; König, P.; Kunze, C. My hands are running away—Learning a complex nursing skill via virtual reality simulation: A randomised mixed methods study. BMC Nurs. 2023, 22, 222.
[75] Shujuan, L.; Mawpin, T.; Meichan, C.; Weijun, X.; Jing, W.; Biru, L. The use of virtual reality to improve disaster preparedness among nursing students: A randomized study. J. Nurs. Educ. 2022, 61, 93–96.

الإمكانات التحويلية لتقنيات الواقع الافتراضي في التعليم الصحي: مراجعة فعالية التدريب وتعليم المرضى

الملخص

الخلفية :اكتسب دمج تقنيات الواقع الافتراضي (VR) في التعليم الصحي زخمًا كبيرًا، حيث يوفر نهجًا مبتكرًا لتحسين تدريب العاملين في مجال الرعاية الصحية. تواجه الطرق التقليدية في التعليم قيودًا مثل ضيق الوقت وتنوع محدود للسيناريوهات السريرية. يوفر الواقع الافتراضي فرصة للتغلب على هذه التحديات من خلال تقديم تجارب تعليمية غامرة وقابلة للتكرار.

الطرق :قيمت هذه المراجعة المنهجية والتحليل التلوي فعالية الواقع الافتراضي(VR) ، والواقع المعزز(AR) ، والواقع المختلط (MR) في تدريب الرعاية الصحية. تم إجراء بحث شامل في قواعد بيانات متعددة لتحديد التجارب العشوائية المضبوطة (RCTs) المنشورة في الفترة بين 2014 و 2023. تضمنت التحليلات دراسات عبر تخصصات صحية مختلفة، مع التركيز على اكتساب المعرفة، وتطوير المهارات، ومواقف المتعلمين.

النتائج :شملت المراجعة 45 دراسة، وكشفت أن الواقع الافتراضي حسّن بشكل كبير درجات المعرفة مقارنة بأساليب التعليم التقليدية (SMD 0.28).كان الواقع الافتراضي فعالًا بشكل خاص في التعليم الطبي والتمريضي، حيث عزز اكتساب المهارات (SMD 0.23) وساهم في تعزيز مواقف إيجابية تجاه التعلم .(SMD 0.65) ومع ذلك، أشارت بعض الدراسات إلى عدم وجود فروق كبيرة في الاحتفاظ بالمعرفة مقارنة بالطرق التقليدية، مما يبرز التباين في فعالية التدريب باستخدام الواقع الافتراضي.

الخلاصة :تُظهر تقنيات الواقع الافتراضي إمكانات كبيرة لتحسين التعليم الصحي من خلال تعزيز المعرفة والمهارات ورضا المتعلمين. ومع ذلك، فإن التباين في نتائج الدراسات والحاجة إلى مزيد من البحث حول طرق الواقع الافتراضي المختلفة تؤكد أهمية الاستمرار في استكشاف التطبيقات الأكثر فعالية للواقع الافتراضي في التدريب الطبي.

الكلمات المفتاحية :الواقع الافتراضي، التعليم الصحي، مراجعة منهجية، اكتساب المعرفة، تطوير المهارات.