



Exploring the Potential of Virtual Reality (VR) in Developing Students' Thinking Skills: A Narrative Review of the Last Five Years

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Article Info	Abstract
Article History Received: November 2024; Revised: December 2024; Published: December 2024	Addressing the persistent issue of inadequate critical thinking skills among students, this study examines the potential of Virtual Reality (VR) to transform educational practices. Traditional teaching methods often prioritize rote memorization, limiting opportunities for higher-order cognitive processes such as analysis, synthesis, and evaluation. This narrative review synthesizes findings from the past five years, focusing on VR's ability to enhance thinking skills. Employing a systematic literature search via Scopus, 24 reviewed studies were analyzed, highlighting VR's immersive and interactive capabilities in fostering critical thinking, problem-solving, and engagement. Results indicate that VR surpasses traditional methods by offering experiential learning scenarios, promoting collaboration, and addressing diverse educational needs. Applications in STEM and professional education demonstrate improved cognitive outcomes, including spatial reasoning, decision-making, and retention of abstract concepts. However, challenges such as high costs, infrastructural constraints, and teacher training gaps hinder widespread adoption. Ethical considerations around data privacy and inclusivity further underscore the need for strategic implementation. This study concludes that VR holds transformative potential in education, provided challenges are addressed through targeted investments, interdisciplinary innovations, and inclusive practices. Future research should emphasize long-term studies and integrate emerging technologies like AI and AR to maximize VR's impact on cognitive skill development.
Keywords Virtual reality; Thinking skill; Critical thinking; Problem-solving; Educational practices; Technology integration	
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How to Cite	Faresta, R. A., Nicholas, T. Z. S. B., Chi, Y., Sinambela, I. A. N., & Mopoliu, A. Z. (2024). Exploring the Potential of Virtual Reality (VR) in Developing Students' Thinking Skills: A Narrative Review of the Last Five Years. <i>International Journal of Essential Competencies in Education</i> , 3(2), 217-239. https://doi.org/10.36312/ijece.v3i2.2407

INTRODUCTION

The issue of low student thinking skills, especially critical thinking, has long been a significant concern in contemporary education. Across various educational systems, there remains a persistent gap in students' ability to engage in higher-order cognitive processes such as analysis, synthesis, and evaluation. This shortfall in cognitive development is not merely a consequence of individual student shortcomings, but rather a broader reflection of systemic challenges within educational methodologies and environments. Traditional teaching methods, which have been prevalent for decades, often emphasize rote memorization and passive learning, overlooking the cultivation of more advanced cognitive

abilities like critical thinking. As a result, students are often ill-prepared to navigate complex problem-solving scenarios or engage deeply with new information (Kantek & Yıldırım, 2019; Susanti, 2024).

Recent studies have highlighted how such educational practices hinder the development of critical thinking. In many classrooms, the dominant instructional approach involves teacher-centered lectures, where information is delivered unidirectionally from the educator to the students. This passive mode of learning leaves little room for active engagement or critical reflection, thereby stifling the development of analytical and problem-solving skills (Arifah, 2023; Fahim & Sa'epour, 2011). Students in these environments tend to focus on memorization and recall, neglecting the deeper understanding necessary for critical thought. As a result, their ability to critically analyze and synthesize complex issues remains underdeveloped, which ultimately limits their capacity to succeed in higher education and beyond (Firdaus et al., 2015).

Moreover, the context in which students learn significantly influences the development of their cognitive skills. Factors such as classroom size, teaching methods, and assessment practices play an essential role in shaping students' thinking processes. Research has shown that larger class sizes and conventional methods of instruction typically result in poorer outcomes in critical thinking assessments. Conversely, smaller class sizes with more interactive, student-centered learning environments foster better engagement and deeper cognitive processing (Miarti et al., 2021). These findings suggest that, in order to cultivate critical thinking, educational settings need to move away from traditional methods and adopt more interactive, engaging approaches that require students to take an active role in their learning. However, in many educational contexts, the shift toward these more dynamic forms of learning has been slow and inconsistent, leaving many students with inadequate critical thinking skills.

As the challenges surrounding critical thinking continue to surface, educational researchers and practitioners have turned to technology to explore its potential as a catalyst for cognitive skill development. Among the various technological tools emerging in education, Virtual Reality (VR) has gained particular attention for its capacity to create immersive and interactive learning experiences that foster higher-order thinking. VR enables students to step beyond the constraints of traditional classrooms by offering them a space in which they can engage with content in new and dynamic ways. The immersive nature of VR allows students to interact with and manipulate their learning environment, providing opportunities for experiential learning and deeper cognitive engagement (Kyaw et al., 2019; Beverly et al., 2022).

The unique attributes of VR present a powerful tool for promoting critical thinking, problem-solving, and other complex cognitive skills. In contrast to traditional forms of education, which often present information in a static and passive manner, VR immerses students in dynamic, experiential learning contexts. For example, students can explore historical events, conduct scientific experiments, or visualize complex mathematical concepts through simulations that place them directly in the midst of the action (Campos et al., 2022; Lie et al., 2023). These interactive experiences require students to think critically, make decisions, and solve problems in real-time, which fosters the development of essential cognitive skills. In this sense, VR has the potential to transcend the limitations of conventional instruction and offer students opportunities to engage in active, hands-on learning, which is crucial for developing higher-order thinking abilities.

Additionally, VR has been shown to enhance learning outcomes in specific educational contexts, particularly in science, technology, engineering, and mathematics (STEM)

education. Research has demonstrated that VR applications can significantly improve students' understanding of abstract concepts by offering visualizations that are otherwise difficult to grasp through traditional media like textbooks or lectures (Beverly et al., 2022). The capacity of VR to provide realistic simulations has proven valuable in STEM fields, where students are often required to visualize complex processes and phenomena. For instance, VR simulations can help students visualize molecular structures, anatomical systems, or the principles of physics, enabling them to interact with and manipulate these abstract concepts in ways that promote deeper understanding (Campos et al., 2022). Furthermore, the ability to engage emotionally with VR experiences can lead to enhanced retention of information, as students are more likely to remember content when they are emotionally invested in the learning process (Vesisenaho et al., 2019; Ferdinand et al., 2023).

Despite the promising potential of VR, its integration into educational systems is not without challenges. One of the most significant barriers to the widespread adoption of VR in education is the cost of the technology. High-quality VR systems and content require substantial financial investment, which may be beyond the reach of many educational institutions, particularly in developing countries or low-budget settings. Additionally, the successful implementation of VR in the classroom requires proper teacher training to ensure that educators are equipped with the skills necessary to use VR tools effectively. Without appropriate training and support, there is a risk that VR technology could be underutilized or misused, diminishing its potential to enhance learning outcomes. Furthermore, VR applications must be aligned with educational objectives and curricula to ensure that they provide meaningful learning experiences. If VR tools are not designed with pedagogical goals in mind, they may fail to engage students in ways that support critical thinking and deeper learning (Fransson et al., 2020).

Despite these challenges, the integration of VR into education holds considerable promise for addressing the long-standing issue of low student thinking skills. As educational systems continue to evolve in response to the needs of the 21st century, VR offers a valuable tool for transforming the learning experience and fostering the development of cognitive skills necessary for success in an increasingly complex world. By providing immersive, interactive learning environments, VR can create opportunities for students to engage with content in ways that are both meaningful and intellectually stimulating. As such, VR is positioned to play a significant role in reshaping the educational landscape and enhancing students' thinking skills in the years to come (González-Pérez & Ramírez-Montoya, 2022; Kim & Im, 2022). The development of critical thinking skills in students remains a critical challenge in modern education. While the integration of technology, particularly VR, presents a viable solution, its successful implementation requires overcoming challenges such as cost, teacher training, and alignment with educational objectives. Nevertheless, the potential of VR to foster critical thinking, problem-solving, and other cognitive skills is immense, and its continued exploration in educational contexts will be crucial for preparing students for the complexities of the future. As this research seeks to explore the potential of VR in developing students' thinking skills, it is important to critically assess the available literature from the past five years, to identify best practices and key challenges that may guide future implementation strategies.

Study Objectives and Novelty

This study aims to explore the potential of Virtual Reality (VR) in enhancing students' thinking skills, particularly through a narrative review of studies conducted over the last five years. The specific objectives of this research are as follows:

1. To identify the role of Virtual Reality in fostering critical thinking and problem-solving skills in educational contexts.
2. To analyze the effectiveness of VR-based learning compared to traditional teaching methods in developing higher-order thinking skills.
3. To examine the challenges and limitations associated with the integration of VR technology into educational practices.
4. To provide recommendations for leveraging VR as a tool to enhance cognitive skill development in students.

The novelty of this study lies in its targeted exploration of how Virtual Reality (VR) can transform educational practices by addressing the critical issue of underdeveloped thinking skills among students. Unlike previous research that broadly discusses VR's technological benefits, this study provides an in-depth analysis of VR's direct impact on fostering higher-order cognitive processes such as critical thinking and problem-solving. It bridges the gap between the theoretical potential of VR and its practical implications for educational outcomes.

This research uniquely highlights VR's immersive and interactive features, emphasizing its role in creating experiential learning environments that enable active engagement. By examining VR's applications in STEM education, professional training, and collaborative learning, the study illustrates its capacity to make abstract concepts tangible, simulate complex scenarios, and promote teamwork. For instance, VR's ability to enhance spatial visualization and decision-making skills is presented as a breakthrough in addressing limitations of traditional teaching methods.

Moreover, the study extends beyond identifying VR's benefits by addressing the challenges associated with its integration, including cost, accessibility, and ethical concerns such as data privacy. Unlike prior works, it offers actionable recommendations to navigate these obstacles, such as leveraging scalable technologies, prioritizing educator training, and promoting inclusive design. The integration of emerging technologies like Artificial Intelligence (AI) is also proposed to further enhance VR's educational impact.

By focusing on VR's unique capacity to address systemic gaps in cognitive skill development and offering practical solutions for implementation, this study contributes significantly to the evolving discourse on educational innovation. Its findings provide a roadmap for leveraging VR as a transformative tool to meet the demands of 21st-century learning environments.

METHOD

Study Design and Approach

This study employed a Narrative Literature Review (NLR) methodology to explore the potential of Virtual Reality (VR) in enhancing students' thinking skills. The NLR method was chosen for its ability to synthesize diverse findings, enabling a detailed and comprehensive understanding of VR's educational impact. Specifically, the study focused on how VR can foster critical thinking, problem-solving, and cognitive abilities, particularly in the context of higher-order learning. By integrating findings from multiple sources, this approach allowed for a nuanced evaluation of VR's capabilities compared to traditional teaching methods. To ensure the study's relevance, the review concentrated on research published within the last five years, capturing recent technological advancements and educational applications.

The decision to focus on the 2020–2024 period was driven by the rapid evolution of VR technology and its increasing integration into educational practices during this timeframe. Advances in hardware, software, and pedagogical applications of VR have surged in recent

years, providing richer insights and more robust empirical evidence of its effectiveness. Additionally, this period reflects a post-pandemic shift in educational priorities, with technology adoption accelerating to address gaps in traditional teaching methods. This temporal scope ensures that the study captures the most up-to-date perspectives and innovations, offering relevant recommendations for future educational strategies.

Literature Search Strategy

The study utilized Scopus as the primary database for sourcing articles, given its extensive repository of peer-reviewed academic publications across disciplines. A carefully constructed Boolean search string was used to identify relevant literature, incorporating keywords and logical operators such as [("Virtual Reality" OR VR) AND (enhanc OR improv OR develop OR foster OR boost) AND (student OR learner OR pupil) AND ("thinking skills" OR "cognitive skills" OR "critical thinking" OR "problem-solving skills")]. The inclusion of synonyms and alternative terms ensured that the search captured a broad spectrum of studies relevant to the objectives. Furthermore, the search was restricted to articles published between 2020 and 2024, ensuring that only the latest and most pertinent findings were considered.

To enhance precision, the study applied additional filters such as language (English) and publication type (journal articles and conference proceedings). This selection process excluded non-peer-reviewed sources, outdated studies, and articles that did not directly address VR's impact on cognitive skills. These measures were critical to maintaining the review's focus on high-quality and relevant literature. Ultimately, this meticulous search strategy resulted in the identification of 567 initial articles, which were subsequently screened for their relevance and methodological rigor.

Inclusion and Exclusion Criteria

A strict set of inclusion and exclusion criteria was applied to ensure that the selected studies aligned with the research objectives. Articles were included if they were peer-reviewed, published between 2020 and 2024, and specifically addressed VR's role in enhancing cognitive skills such as critical thinking or problem-solving. Only English-language publications were considered to ensure accessibility and consistency in analysis. Furthermore, studies were required to demonstrate methodological soundness and relevance to educational outcomes, with particular emphasis on immersive and interactive learning contexts.

Exclusion criteria eliminated studies that fell outside the defined timeframe or were irrelevant to the study's focus. Articles lacking sufficient methodological detail or published in low-quality venues were also excluded to maintain the credibility of the review. This rigorous filtering process involved a multi-stage review of titles, abstracts, and full texts, ultimately narrowing the selection to 24 high-quality studies. These studies formed the foundation for the thematic analysis, ensuring a robust and reliable synthesis of the literature.

Data Collection and Extraction

Data collection involved a systematic and structured approach to ensure that relevant information was captured from each selected study. A data extraction template was used to record key details, including study objectives, methodologies, findings, and conclusions. This template facilitated the identification of recurring themes, such as the immersive nature of VR, its capacity to enhance critical thinking, and its potential for improving problem-solving abilities. Additionally, the process highlighted VR's applications across different educational domains, from STEM education to professional training, providing a comprehensive view of its impact.

The extracted data were subsequently categorized into thematic groups, focusing on VR's ability to address cognitive skill gaps and its challenges in implementation. This thematic approach allowed for a nuanced understanding of how VR compares to traditional teaching methods. By analyzing patterns and trends across the selected studies, the review provided valuable insights into VR's transformative potential in education. This step also ensured that findings were synthesized in a manner consistent with the study's objectives, enhancing the overall coherence of the review.

Quality Assessment

Each selected article underwent a rigorous quality assessment process to ensure the reliability and validity of the findings. Quality indicators included the journal's impact factor, citation metrics, and the methodological robustness of the study. Articles from high-impact journals or those employing innovative research designs were prioritized, reflecting the study's emphasis on credible and high-quality sources. This assessment was critical in mitigating biases and ensuring that the review's conclusions were grounded in reliable evidence.

Furthermore, the quality assessment involved a detailed examination of each study's alignment with the review's objectives. This included evaluating the relevance of the findings to educational practices and the clarity of the methodological approach. Studies with ambiguous objectives or inadequate data reporting were excluded to maintain the integrity of the analysis. By applying these stringent criteria, the review established a solid foundation for discussing VR's potential in enhancing cognitive skills, supported by robust and credible evidence.

Ethical Considerations

All reviewed articles were publicly available, and proper citations were maintained throughout the study to acknowledge the original contributions of authors. Ethical standards were upheld by avoiding any misrepresentation or misuse of the reviewed studies. Additionally, the review adhered to principles of transparency and accountability, ensuring that the findings were presented honestly and without bias. These ethical practices underscored the credibility of the research process and reinforced the integrity of the study.

Given the public availability of the reviewed literature, no ethical approval was required for this study. However, the ethical implications of the findings, particularly in relation to VR's application in education, were carefully considered. This included reflecting on issues such as data privacy, accessibility, and the ethical deployment of VR technologies in learning environments. These considerations added depth to the review and highlighted the importance of responsible innovation in education.

RESULTS AND DISCUSSION

A systematic review utilizing the Boolean string [("Virtual Reality" OR VR) AND (enhanc OR improv OR develop OR foster OR boost) AND (student OR learner OR pupil) AND ("thinking skills" OR "cognitive skills" OR "critical thinking" OR "problem-solving skills")] resulted in the identification of 567 documents from Scopus. The distribution by year (Figure 1a) reveals a significant growth in publications, with 362 documents appearing within the last five years (2020–2024). This trend underscores the increasing academic focus on VR's role in education.

The document types (Figure 1b) predominantly consisted of journal articles (40.7%) and conference papers (41.1%), with minimal representation from reviews, book chapters, and editorials. These findings highlight the methodological diversity in exploring VR's

educational impact. Additionally, subject areas (Figure 1c) showed concentration in Computer Science (28.3%) and Social Sciences (23.1%), with notable contributions from Engineering (15.6%) and Medicine (5.4%). This distribution emphasizes VR's interdisciplinary relevance.

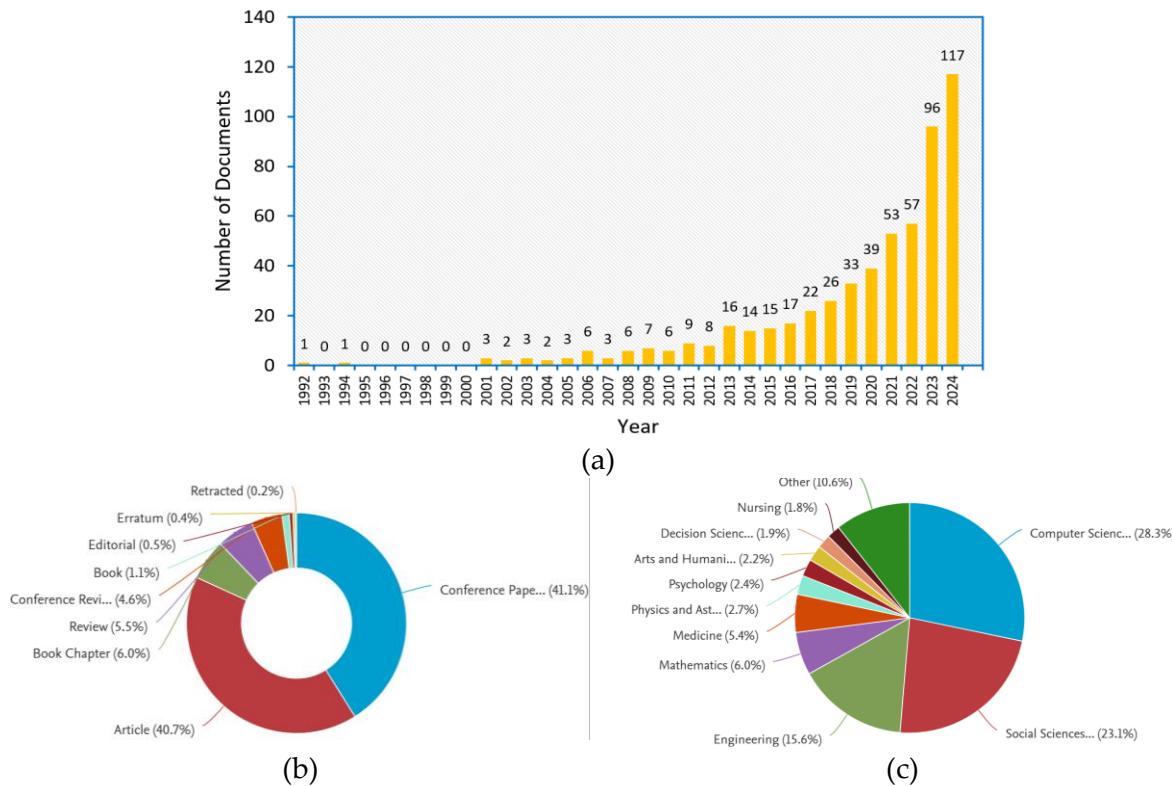


Figure 1. Documents distribution: (a) by year, (b) by type, and (c) by subject area

Following rigorous inclusion and exclusion criteria, 24 studies were selected based on their relevance to VR's impact on cognitive skills. These studies, summarized in Table 1, offer diverse perspectives on VR's applications across various educational domains, including STEM, professional training, and collaborative learning environments. The selected works demonstrate VR's capacity to create engaging, experiential settings that enhance knowledge retention, practical skill acquisition, and complex cognitive processing. Such findings affirm VR's potential as a transformative tool for addressing limitations inherent in traditional pedagogical approaches.

Table 1 serves as a foundational overview of VR's utility, showcasing evidence of its success in promoting spatial visualization, decision-making, and innovative thinking in fields ranging from engineering to nursing. Additionally, the table highlights the innovative integration of VR with hybrid models and other technologies to enrich educational outcomes further. These insights not only address the research objectives but also emphasize the interdisciplinary relevance and adaptability of VR in advancing cognitive skill development across diverse learning contexts.

Table 1. Overview of studies on the use of virtual reality (VR) in education

No. Author(s) & Year	Study Title	Study Findings
1. Behunova et al. (2022)	Enhancing Education Process Supported by VR	Improved learning processes supported by VR in educational settings.

No. Author(s) & Year	Study Title	Study Findings
2. Ramesh et al. (2022)	3D Printing Ophthalmology Related Models for Enhancing Learning.	Enhanced self-directed learning using tactile toolkits in ophthalmology.
3. Liu et al. (2023)	Effectiveness of VR in Nursing Education: A Systematic Review and Meta-Analysis.	VR led to better retention and practical application of nursing skills.
4. Lin et al. (2023)	Fostering Complex Professional Skills with Interactive Simulation Technology.	Flipped learning approach with VR improved professional skills and critical thinking.
5. Xie et al. (2023)	Integrating Immersive Experience into Hybrid Education: A Case Study in Fintech.	Improved knowledge retention and engagement in fintech education with hybrid VR models.
6. Mahindru et al. (2023)	Metaverse Unleashed: Augmenting Creativity and Innovation in Business Education.	Enhanced creativity and innovation in business education through metaverse applications.
7. Lee et al. (2023)	Enhancing Critical Thinking Through Puzzle Box Integration in VR Game-Based Learning.	Improved critical thinking and engagement using VR-integrated game-based learning.
8. McCloskey et al. (2024)	Embedding Civil Engineering Understanding through the Use of Interactive VR.	Enhanced understanding of civil engineering concepts through interactive VR simulations.
9. Huang et al. (2024)	Empowering Virtual Reality with Feedback and Reflection in Hands-On Learning.	Improved engagement and higher-order thinking skills through reflective VR experiences.
10. Zhou & Fang (2024)	Reform and Application of Intelligent Manufacturing Professional Training Mode.	Enhanced outcomes in intelligent manufacturing education with innovative talent training models.
11. Lee & Baek (2024)	Development and Effects of Adult Nursing Education Programs Using VR Simulations.	VR simulations improved nursing students' competence in clinical decision-making.
12. Azzam et al. (2024)	Development of Spatial Visual Abilities among STEM Students via Mixed Reality.	Significant enhancement in spatial visualization skills critical for STEM fields.
13. Xu et al. (2024)	Enhancing Green Building Teaching for Architecture Students through VR.	Improved understanding of sustainable design principles using VR for green buildings.

No. Author(s) & Year	Study Title	Study Findings
14. Kazura et al. (2024)	Enhancing Maritime Education and Training Through Virtual and Augmented Reality.	Better situational awareness and decision-making skills in maritime training using immersive technologies.
15. Burgos-Lopez et al. (2024)	Virtual Reality to Enhance User Satisfaction in an Engineering Innovation Project.	Higher satisfaction levels reported in engineering innovation projects using VR.
16. Parsley (2024)	Enhancing Engineering Education Through Hands-On VR Training Experiences.	Improved skills in continuous improvement processes using VR for engineering education.
17. Porat & Ceobanu (2024)	Enhancing Spatial Ability: A New Integrated Hybrid Training Approach.	Enhanced spatial ability through hybrid training integrating VR.
18. Kim et al. (2024)	Impact of VR Mental Health Nursing Simulation on Nursing Students' Competence.	Improved competence in mental health care scenarios using VR simulations.
19. Angraini et al. (2024)	AR-Based Learning Media on Mathematical Computational Thinking Ability.	Improved computational thinking abilities using AR-based learning tools.
20. Antonova et al. (2024)	Modern Technologies and Their Impact on Educational Transformations.	Highlighted the transformative potential of modern technologies in education.
21. Mierluş-Mazilu & Yilmaz (2024)	Teaching Mathematics in STEM Education.	Enhanced STEM learning outcomes through VR-integrated teaching methods.
22. Lai et al. (2021)	Study on Enhancing AIoT Computational Thinking Skills by Plot Image-Based VR.	Enhanced AIoT computational thinking skills using VR technologies.
23. Ismael (2024)	A Multi-Tool Approach in Integrating Entrepreneurship into Engineering Education.	Improved entrepreneurial skills using multi-tool VR approaches.
24. Maricic et al. (2024)	Innovative Technologies in Computer Education: Integration of VR, CAD/CAM.	Enhanced computer education outcomes integrating VR and gamification.

The Role of Virtual Reality in Fostering Critical Thinking and Problem-Solving Skills in Educational Contexts

Virtual Reality (VR) has emerged as a powerful tool in education, creating immersive environments that enhance students' cognitive engagement and skill development. As critical thinking and problem-solving become increasingly vital in a rapidly evolving world, VR provides innovative ways to foster these abilities. This manuscript explores how VR

contributes to these educational outcomes, drawing from recent studies and applications across diverse fields.

A core advantage of VR lies in its ability to provide experiential learning experiences. Unlike traditional classroom settings, where theoretical knowledge dominates, VR immerses learners in practical, real-world scenarios that demand active engagement. McCloskey et al. (2024) demonstrated how VR facilitates understanding of complex engineering systems through interactive simulations, allowing students to test hypotheses and analyze outcomes in real-time. Similarly, Parsley (2024) highlighted the use of VR in manufacturing education, where students develop continuous improvement skills by navigating realistic industrial challenges. Such experiences not only promote technical expertise but also encourage the application of critical thinking in dynamic settings.

The integration of VR with spatial visualization tasks has also proven effective in STEM education. Azzam et al. (2024) showed that manipulating 3D models in virtual environments significantly improves spatial reasoning, a key component of problem-solving in fields like mathematics and engineering. Moreover, Porat and Ceobanu (2024) emphasized that VR-based hybrid training for engineering students enhanced their ability to analyze and innovate in architectural designs. By bridging the gap between theoretical constructs and their practical applications, VR ensures learners acquire analytical competencies necessary for real-world problem-solving.

Feedback mechanisms embedded in VR further strengthen its educational value by promoting reflective thinking. Huang et al. (2024) examined the impact of integrated feedback loops in VR platforms, finding that they significantly enhance higher-order thinking skills by prompting students to reflect on their decision-making processes. This reflective component aligns with experiential learning theory, which advocates learning through concrete experiences followed by reflection. Lin et al. (2023) expanded on this idea, demonstrating that VR-based flipped learning approaches help students identify their biases and reassess strategies, thereby deepening their critical thinking abilities.

In professional and vocational training, VR has shown remarkable success in cultivating decision-making skills. Lee and Baek (2024) explored its application in nursing education, where VR simulations of emergency scenarios improved students' competence under pressure. Similarly, Kazura et al. (2024) found that VR enhanced maritime students' situational awareness by replicating high-stakes scenarios in controlled environments. These findings underscore VR's potential to prepare learners for real-world challenges, equipping them with the critical skills necessary for effective problem resolution.

The collaborative potential of VR also contributes to its educational effectiveness. Xu et al. (2024) explored the role of VR in architecture education, highlighting how collaborative virtual environments enable students to co-create sustainable designs. This shared experience fosters critical thinking by encouraging learners to debate perspectives, evaluate trade-offs, and build consensus. Similarly, Lee et al. (2023) integrated puzzle-solving tasks in VR-based digital games, finding that collaborative problem-solving significantly boosted students' engagement and analytical skills. By emphasizing teamwork and communication, VR supports not only individual cognitive growth but also the social dimensions of learning.

Cultural and contextual adaptability is another critical feature of VR in education. Angraini et al. (2024) illustrated how localized VR content in mathematics education helped students develop computational thinking skills relevant to their cultural contexts. Similarly, Lai et al. (2021) utilized VR to enhance AIoT computational thinking through image-based simulations, showcasing its potential to address region-specific challenges. This adaptability

ensures that VR remains relevant across diverse educational settings, fostering meaningful and impactful learning experiences.

The theoretical underpinnings of VR's success in education draw from constructivist and experiential learning paradigms. Constructivist theory emphasizes knowledge construction through interaction with the environment, a principle VR operationalizes through immersive, interactive scenarios. Experiential learning further complements this by advocating for concrete experiences followed by reflective observation. Burgos-Lopez et al. (2024) demonstrated how VR supports these frameworks in engineering innovation projects, enabling students to experiment, fail, and learn through iterative processes. This combination ensures that VR not only engages learners but also facilitates enduring cognitive development.

Despite its potential, implementing VR in education presents challenges such as high costs, technological complexities, and the need for instructor training. Liu et al. (2023) conducted a systematic review of VR applications in nursing education, identifying resource constraints as a common barrier to widespread adoption. However, advances in technology and partnerships between educational institutions and tech providers could address these issues. For instance, Mahindru et al. (2023) explored how the integration of VR in business education through metaverse platforms enhanced creativity and innovation, suggesting scalable models for broader adoption.

Looking forward, the future of VR in education depends on interdisciplinary research and development. Studies such as those by Xie et al. (2023), which integrated AI with VR to create adaptive learning environments, highlight the potential for personalized education pathways that cater to individual needs. Moreover, Ramesh et al. (2022) explored the use of 3D printing alongside VR to enhance tactile learning, indicating opportunities for multi-tool integration in education. By combining insights from psychology, technology, and pedagogy, future innovations could further optimize VR's educational impact.

In conclusion, VR represents a groundbreaking tool for fostering critical thinking and problem-solving skills in education. Its ability to provide immersive, interactive, and reflective learning environments positions it as a transformative force in modern pedagogy. By enabling experiential learning, promoting collaboration, and addressing contextual nuances, VR transcends the limitations of traditional teaching methods. As challenges related to accessibility and cost are addressed, the role of VR in education is set to expand, offering new opportunities to prepare learners for the complexities of the contemporary world. With continued research and innovation, VR is poised to redefine the landscape of educational practice, empowering students to think critically, solve problems effectively, and navigate the demands of an ever-changing global environment.

Effectiveness of VR-Based Learning Compared to Traditional Teaching Methods in Developing Higher-Order Thinking Skills

Virtual Reality (VR)-based learning has emerged as a transformative approach in education, offering significant advantages over traditional teaching methods, particularly in developing higher-order thinking skills. These cognitive abilities, encompassing critical analysis, synthesis, and evaluation, are essential for academic achievement and professional success in the modern era. The immersive and interactive capabilities of VR facilitate a learning experience that is more engaging, practical, and effective than conventional pedagogies, which often rely on passive information delivery and rote memorization. Through a combination of experiential learning, emotional engagement, and adaptive

feedback, VR is revolutionizing how students approach complex problems, develop critical skills, and apply their knowledge in real-world contexts.

The strength of VR in enhancing higher-order thinking lies in its immersive nature, which promotes active engagement and retention of information. Studies have consistently shown that learners immersed in VR environments retain knowledge more effectively than those in traditional classrooms. For instance, Liu et al. (2023) conducted a systematic review of VR applications in nursing education, finding that students trained with VR demonstrated superior knowledge retention and comprehension. This improved retention is attributed to the hands-on learning experiences VR offers, where students actively participate in realistic scenarios that mirror professional challenges. Similarly, McCloskey et al. (2024) explored the use of VR in civil engineering education, demonstrating that interactive 3D models enhanced students' conceptual understanding and practical application of engineering principles. By engaging learners in dynamic environments where they can manipulate variables and observe outcomes, VR fosters a deeper connection with the material, bridging the gap between theoretical concepts and their real-world implications.

The benefits of VR extend beyond retention to the development of critical thinking and problem-solving skills. Unlike traditional teaching methods, which often emphasize static problem-solving approaches, VR introduces learners to dynamic scenarios that require real-time decision-making and adaptability. Lin et al. (2023) highlighted the effectiveness of VR-based flipped learning models, noting that students exposed to VR scenarios developed more advanced problem-solving abilities compared to their peers in lecture-based settings. These students were better equipped to analyze complex challenges, evaluate multiple variables simultaneously, and implement creative solutions. Huang et al. (2024) further emphasized the role of iterative feedback in VR environments, showing that the opportunity to reflect on and refine strategies enhanced students' critical thinking. This iterative process, which mirrors the complexities of real-world problem-solving, encourages learners to question their assumptions, evaluate their choices, and adapt their approaches based on new insights.

A key advantage of VR is its ability to address the limitations of traditional teaching methods, particularly in accommodating diverse learning needs. Traditional classrooms often struggle to provide the hands-on experiences necessary for understanding abstract concepts, leaving many students disengaged or unable to grasp the material fully. VR overcomes this challenge by offering personalized and experiential learning opportunities tailored to individual needs. In maritime education, Kazura et al. (2024) demonstrated that VR simulations enabled students to practice navigation and safety protocols in lifelike scenarios, which were difficult to replicate in traditional classrooms. This hands-on experience not only improved skill acquisition but also built confidence in applying theoretical knowledge to real-world situations. Similarly, Lee and Baek (2024) found that VR simulations in nursing education significantly enhanced students' clinical decision-making skills by immersing them in high-pressure environments that would be challenging or impractical to recreate in conventional training.

The ability of VR to engage students on an emotional level further distinguishes it from traditional methods. Emotional engagement has been shown to enhance cognitive processing, making learning experiences more memorable and impactful. Liu et al. (2023) noted that students in VR environments often exhibit heightened emotional investment, leading to improved focus, motivation, and retention. This emotional connection is particularly valuable in disciplines where abstract concepts can be difficult to internalize. For example, Mahindru et al. (2023) observed that VR experiences in business education fostered greater creativity and problem-solving abilities by immersing students in complex, real-world-inspired

scenarios. Similarly, Xie et al. (2023) reported that students participating in hybrid VR courses in fintech education demonstrated better understanding and application of financial principles due to their increased engagement and motivation. By making learning more relatable and emotionally resonant, VR enhances students' ability to retain information and apply it effectively in diverse contexts.

The comparative advantages of VR-based learning are evident across a wide range of disciplines, from STEM and healthcare to business and architecture. In STEM education, Azzam et al. (2024) demonstrated that VR's interactive features significantly improved spatial visualization skills among engineering students, enabling them to tackle complex design challenges with greater confidence. In healthcare, Liu et al. (2023) and Lee and Baek (2024) found that VR simulations enhanced clinical reasoning and decision-making skills, outcomes that are difficult to achieve through traditional lectures or text-based instruction. In architecture, Xu et al. (2024) highlighted how VR enabled students to design and evaluate green buildings in virtual environments, allowing them to apply theoretical knowledge in practical contexts while critically assessing the environmental impact of their decisions. These examples underscore VR's versatility and effectiveness in preparing students for real-world challenges.

One of the most significant criticisms of traditional teaching methods is their inability to replicate the complexity and unpredictability of real-world scenarios. VR addresses this limitation by creating immersive environments where students can experiment, learn, and make mistakes without real-world consequences. Kazura et al. (2024) emphasized that VR's ability to simulate high-stakes maritime environments allowed students to practice navigation and decision-making skills safely and effectively. This capability is particularly valuable in fields where traditional simulations are costly, dangerous, or logistically challenging. Maricic et al. (2024) further illustrated how VR integration with CAD/CAM and 3D modeling enabled engineering students to work on projects that would otherwise require extensive physical resources, democratizing access to high-quality experiential learning.

Despite its transformative potential, VR-based learning is not without challenges. High implementation costs, technological complexities, and the need for specialized educator training are significant barriers to widespread adoption. These challenges are particularly pronounced in low-resource settings, where traditional methods may remain the only viable option. However, as VR technology continues to evolve, its affordability and accessibility are expected to improve. Mahindru et al. (2023) suggested that partnerships between educational institutions and technology developers could facilitate the creation of cost-effective VR solutions, enabling broader adoption. Furthermore, advancements in AI and machine learning hold promise for enhancing VR's capabilities. Lai et al. (2021) explored the integration of AI-powered tools into VR systems, demonstrating how adaptive learning environments can cater to individual student needs and learning styles, paving the way for more personalized and effective educational experiences.

In conclusion, the comparative analysis of VR-based learning and traditional teaching methods reveals that VR offers unparalleled advantages in fostering higher-order thinking skills. By providing immersive, interactive, and adaptive learning experiences, VR transforms education from a passive, theoretical process into an active, experiential journey. Its ability to enhance retention, critical thinking, and problem-solving skills positions it as a revolutionary tool for preparing students to navigate the complexities of the modern world. While traditional methods remain valuable in certain contexts, particularly for their cost-effectiveness and scalability, the potential of VR to reshape the educational landscape is undeniable. As institutions address the challenges of implementation and explore

interdisciplinary innovations, VR is poised to play a central role in equipping students with the skills and knowledge needed to thrive in an increasingly complex and dynamic global environment.

Challenges and Limitations Associated with the Integration of VR Technology into Educational Practices

Integrating Virtual Reality (VR) into educational practices has garnered significant attention as a transformative approach to learning. However, despite its promising potential, the widespread adoption of VR faces numerous challenges and limitations. These barriers span economic, technical, pedagogical, ethical, and logistical dimensions, necessitating strategic planning and multi-stakeholder collaboration to address them effectively. Understanding these challenges is crucial for educational institutions aiming to leverage VR's benefits while ensuring equitable and sustainable implementation.

One of the most pressing issues hindering VR adoption is the high cost associated with its deployment. The upfront investment in hardware, including VR headsets and high-performance computers, is substantial. McCloskey et al. (2024) emphasize that even well-funded institutions struggle to justify these expenditures, particularly when paired with the ongoing costs of maintenance, upgrades, and content development. Developing high-quality, pedagogically sound VR content adds another layer of financial strain, as it often requires specialized expertise and significant time resources. This financial burden disproportionately affects schools in developing regions, where limited budgets already constrain access to basic educational tools (Liu et al., 2023). As technology evolves rapidly, the risk of obsolescence further complicates financial planning, deterring institutions from committing to large-scale VR integration.

Beyond costs, infrastructure limitations present another significant barrier. Effective VR deployment relies on robust technological infrastructure, including high-speed internet, powerful computing resources, and dedicated physical spaces for VR activities. Lin et al. (2023) highlight that many schools, particularly those in rural or underserved areas, lack these foundational requirements, making VR integration unattainable. For instance, maritime education programs studied by Kazura et al. (2024) revealed how inadequate infrastructure prevented institutions from leveraging VR's potential to simulate complex navigational scenarios, limiting its scalability and impact. In regions with unreliable electricity or internet access, even basic VR setups become impractical, further exacerbating the digital divide in education.

The human factor also poses challenges in adopting VR technology. Educators play a central role in the successful implementation of VR, yet many lack the technical training and confidence to use these tools effectively. Lee and Baek (2024) found that educators often express skepticism about adopting VR, citing its complexity and the perceived disruption to established teaching practices. This resistance to change is compounded by a lack of professional development opportunities tailored to VR integration. McCloskey et al. (2024) argue that without comprehensive training programs that address both technical and pedagogical aspects, educators may underutilize or misapply VR, undermining its potential benefits. Overcoming this barrier requires not only skill-building initiatives but also a cultural shift that emphasizes the value of innovative teaching methods.

Aligning VR applications with pedagogical objectives presents another challenge. While VR excels in providing immersive, experiential learning opportunities, its effectiveness hinges on the quality of its design and integration into curricula. Poorly designed VR content can detract from learning, prioritizing novelty over educational substance. Huang et al. (2024)

warn that VR scenarios lacking clear learning outcomes risk disengaging students, as they may struggle to see the relevance of these activities to their broader academic goals. Additionally, creating tailored VR experiences that meet the diverse needs of specialized fields is both time- and resource-intensive. Xu et al. (2024) illustrate this challenge in the context of green building education, where effective VR content required close collaboration between educators and developers—a process often constrained by limited funding and expertise.

Technical challenges further complicate VR adoption in education. VR systems rely on sophisticated hardware and software that are not only expensive but also prone to technical issues. Azzam et al. (2024) report that compatibility problems, software glitches, and user interface complexities frequently disrupt VR activities, frustrating both students and educators. Such disruptions undermine the learning experience, deterring institutions from investing in VR technology. Furthermore, the steep learning curve associated with mastering VR systems discourages some students, particularly those less familiar with advanced technologies. Lee et al. (2023) found that these technical hurdles limited student engagement, reducing the overall educational impact of VR programs.

Health and safety concerns also emerge as significant limitations of VR in educational contexts. Prolonged use of VR devices has been linked to physical discomfort, including eye strain, motion sickness, and fatigue. Liu et al. (2023) highlight that these issues are particularly pronounced during extended VR sessions, where students may experience diminishing returns on their learning engagement due to physical discomfort. Additionally, the immersive nature of VR raises psychological concerns. Huang et al. (2024) point out that highly realistic simulations, especially those involving high-stakes decision-making or emergency scenarios, can induce stress or anxiety in some students, detracting from their overall learning experience.

Equity and accessibility issues further complicate VR integration in education. The high costs and infrastructure demands of VR technology create disparities between well-resourced and underfunded institutions, widening the educational gap. Students in underprivileged schools are less likely to benefit from VR's advantages, perpetuating inequities in access to high-quality learning tools. Kazura et al. (2024) illustrate this challenge in maritime education, where resource constraints left many institutions unable to adopt VR, forcing students to rely on less effective traditional methods. Accessibility concerns also extend to the design of VR systems, which often fail to accommodate students with disabilities. Azzam et al. (2024) emphasize the need for more inclusive VR platforms that consider the needs of learners with mobility impairments, visual challenges, or other disabilities to ensure equitable access.

Ethical and privacy concerns are also gaining attention as VR becomes more integrated into education. Many VR platforms collect extensive user data to personalize learning experiences, raising questions about data security and ethical use. Xu et al. (2024) stress the importance of establishing clear policies to safeguard student data, ensuring it is stored and used responsibly. The immersive nature of VR also raises ethical questions about the potential for manipulation. Overly realistic simulations could influence students' perceptions or behaviors in unintended ways, highlighting the need for robust ethical guidelines in VR content development.

A lack of longitudinal research on VR's impact in education further complicates its integration. While many studies document the short-term benefits of VR, there is limited evidence on its long-term effects on cognitive development and learning outcomes. Lin et al. (2023) note that most existing research focuses on immediate gains, leaving questions about the sustained effectiveness of VR-based learning unanswered. Addressing this gap requires

comprehensive, long-term studies that track the progress of students using VR over extended periods, providing valuable insights into its role in shaping educational trajectories.

To overcome these challenges, a multi-faceted approach is necessary. Reducing costs is a critical priority, and collaborations between educational institutions, governments, and technology providers can help subsidize expenses. McCloskey et al. (2024) advocate for partnerships with industry stakeholders to distribute financial burdens more equitably, making VR technology accessible to a broader range of institutions. Infrastructure improvements are equally important, particularly in underserved areas. Lin et al. (2023) emphasize the need for targeted investments in IT systems, internet connectivity, and dedicated VR spaces to support scalable implementations.

Comprehensive educator training programs are essential for empowering teachers to integrate VR confidently into their teaching practices. Lee and Baek (2024) recommend mentorship initiatives where experienced VR adopters guide less familiar educators, fostering a supportive environment for innovation. Ensuring inclusivity in VR design is also crucial. Azzam et al. (2024) call for the adoption of universal design principles that accommodate diverse learner needs, enhancing equity in access to VR tools.

Ethical considerations must also be addressed through clear guidelines on data privacy and responsible content development. Xu et al. (2024) propose that collaborations with ethicists and policymakers can help establish robust frameworks, ensuring that VR technology is used responsibly and transparently. Finally, addressing the research gap on VR's long-term impact requires sustained investment in longitudinal studies, providing a deeper understanding of its transformative potential in education.

In conclusion, while the integration of VR into educational practices offers significant opportunities, it is accompanied by complex challenges that must be navigated strategically. By addressing financial constraints, infrastructure limitations, technical issues, and ethical concerns through innovation and collaboration, educational institutions can harness the full potential of VR to create inclusive, engaging, and effective learning environments. With the right investments and policies, VR can become a cornerstone of 21st-century education, empowering students to thrive in an increasingly digital world.

Recommendations for Leveraging VR as a Tool to Enhance Cognitive Skill Development in Students

Virtual Reality (VR) represents an innovative frontier in education, offering transformative opportunities to enhance cognitive skill development, particularly in critical thinking, problem-solving, and higher-order analytical abilities. However, realizing VR's full potential requires thoughtful strategies grounded in evidence-based recommendations. Drawing from recent advancements and research insights, this discussion outlines actionable steps to integrate VR effectively into educational practices, ensuring its impact is maximized across diverse learning environments.

The high cost of VR technology often emerges as a primary barrier to its widespread adoption. Institutions need to develop cost-effective strategies through collaborations with industry stakeholders, governments, and non-profits. McCloskey et al. (2024) highlighted the benefits of public-private partnerships, emphasizing how alliances with VR developers can subsidize hardware, software, and content costs. Such partnerships can also facilitate bulk procurement of VR systems, reducing per-unit expenses and making technology accessible to schools with limited budgets. Open-source VR platforms represent another cost-effective solution, offering customizable and budget-friendly alternatives to proprietary systems.

Institutions should also leverage crowdfunding initiatives and educational grants aimed at technology integration to address financial constraints, as suggested by Liu et al. (2023).

Equally critical to VR implementation is the establishment of robust infrastructure to support its deployment. Lin et al. (2023) emphasized the importance of scalable investments in IT systems, reliable internet connectivity, and dedicated VR spaces, particularly in underserved regions. Policymakers must prioritize infrastructure upgrades as part of long-term educational development plans. Mobile VR solutions, which rely on affordable headsets and smartphones, offer practical interim options for institutions with limited resources. These solutions bridge the digital divide, enabling more equitable access to VR's benefits while comprehensive infrastructure development is underway.

A crucial factor in the successful integration of VR is equipping educators with the skills and confidence necessary to use the technology effectively. Lee and Baek (2024) noted that many teachers perceive VR as complex or disruptive to traditional practices, leading to resistance. Comprehensive training programs that address both technical and pedagogical aspects are essential to overcoming these barriers. Such programs should teach educators how to align VR activities with curriculum objectives and incorporate cognitive skill development into lesson plans. Mentorship models, where experienced VR adopters guide their peers, can further accelerate adoption. Additionally, professional development workshops and online courses tailored to VR in education provide scalable options for teacher training, ensuring that educators are well-prepared to leverage this technology effectively.

For VR to serve as a powerful tool for cognitive skill development, its content must be meticulously aligned with pedagogical objectives. Huang et al. (2024) cautioned against designing VR activities that prioritize novelty over substance, noting that superficial engagement undermines cognitive gains. Developers and educators must collaborate to create contextually relevant, subject-specific VR modules. For instance, in nursing education, Liu et al. (2023) demonstrated how VR simulations of real-world medical scenarios foster critical decision-making and problem-solving skills. Customizable VR content allows institutions to adapt experiences to their unique educational needs, ensuring relevance and effectiveness.

Collaboration is another dimension where VR excels in enhancing cognitive skills. Xu et al. (2024) emphasized the benefits of collaborative VR environments in fostering teamwork, communication, and critical thinking. These environments enable students to tackle complex projects together, mirroring professional teamwork scenarios. For example, collaborative VR applications in architecture and engineering allow students to co-design structures, analyze resource allocations, and optimize workflows, all while engaging in dynamic problem-solving. Institutions should prioritize VR tools that include multiplayer or group interaction features, enriching the learning experience and preparing students for real-world collaboration.

Accessibility and inclusivity are fundamental considerations in the equitable deployment of VR technology. Many current VR systems exclude students with disabilities or those from low-resource settings, exacerbating educational disparities. Azzam et al. (2024) advocated for the adoption of universal design principles to make VR systems more inclusive. These principles might include alternative interaction methods for students with limited mobility or the development of content tailored to diverse learning styles. Lightweight VR systems and virtual desktop solutions offer additional pathways to increase accessibility in resource-constrained environments. Policymakers and educational leaders must also establish targeted funding mechanisms to ensure that underprivileged schools can integrate VR into their programs effectively.

The immersive and interactive nature of VR can introduce health and safety challenges that educators and institutions must address proactively. Prolonged use of VR devices has been associated with physical discomfort, such as eye strain and motion sickness, as well as psychological impacts like stress or anxiety during intense simulations (Liu et al., 2023). Institutions should establish usage guidelines that include session time limits, ergonomic considerations, and scheduled breaks. Furthermore, educators should receive training to identify and mitigate potential psychological impacts, ensuring that VR experiences remain supportive of students' well-being. Ongoing research into the long-term effects of VR in education is necessary to refine these safety protocols and inform best practices.

The integration of VR with complementary technologies, such as Artificial Intelligence (AI) and Augmented Reality (AR), offers exciting opportunities to amplify its impact on cognitive skill development. AI-powered VR systems can adapt content dynamically based on individual student needs, providing personalized learning pathways. Huang et al. (2024) demonstrated how adaptive feedback mechanisms enhance problem-solving skills by tailoring suggestions to each learner's progress. Similarly, Xie et al. (2023) explored hybrid VR-AR models in fintech education, finding that these approaches significantly improved engagement and knowledge retention. By combining the strengths of VR, AI, and AR, educators can create hybrid learning environments that seamlessly integrate physical and virtual elements, enriching the educational experience.

Ethical considerations and data privacy are critical concerns as VR becomes increasingly integrated into education. Many VR platforms collect extensive user data to personalize learning experiences, raising questions about data security and ethical use. Xu et al. (2024) emphasized the need for clear policies on data storage, usage, and protection to safeguard student privacy. Institutions must work closely with technology providers to establish transparent practices and ensure compliance with data protection laws. Ethical guidelines should also govern the design and deployment of VR content, avoiding excessively graphic or distressing scenarios that could negatively impact students' mental well-being. Regular audits of VR systems and content can help maintain ethical standards, fostering trust among students, educators, and parents.

Long-term research and development are essential to fully understand and optimize VR's role in education. While numerous studies highlight the short-term benefits of VR, there is a lack of longitudinal research examining its sustained impact on cognitive development. Lin et al. (2023) stressed the importance of investigating VR's effects over time and across diverse learner demographics. Such research can provide valuable insights into how VR influences critical thinking, problem-solving, and learning outcomes, informing future innovations. Collaboration between educational institutions, governments, and technology developers is key to funding and conducting these long-term studies, ensuring that VR remains relevant and impactful in evolving educational landscapes.

In conclusion, leveraging VR to enhance cognitive skill development requires a holistic and strategic approach. Institutions must address financial and infrastructural barriers while prioritizing accessibility, inclusivity, and educator training. Collaborative VR environments and customizable content ensure relevance and engagement, while integration with AI and AR unlocks new dimensions of personalized learning. Adhering to ethical standards and conducting long-term research are essential for sustaining VR's transformative potential. With careful planning, collaboration, and innovation, VR can become a cornerstone of modern education, equipping students with the cognitive skills they need to navigate an increasingly complex and dynamic world. As the technology continues to evolve, its role in shaping the

future of education is bound to expand, offering unprecedented opportunities for learners worldwide.

CONCLUSION

The integration of Virtual Reality (VR) into education has proven to be a transformative force, offering immersive and interactive learning environments that significantly enhance students' cognitive skills. As demonstrated in the reviewed studies, VR facilitates critical thinking, problem-solving, and higher-order cognitive processes by immersing students in experiential learning scenarios that challenge them to engage actively with content. Unlike traditional teaching methods that emphasize rote memorization and passive learning, VR encourages students to analyze, evaluate, and apply knowledge in dynamic contexts. This pedagogical shift is particularly impactful in STEM fields, healthcare, and professional education, where students benefit from realistic simulations that bridge the gap between theoretical constructs and practical applications. Furthermore, VR's capacity to foster collaboration and adapt to cultural and contextual nuances underscores its potential as a versatile and inclusive educational tool.

Despite its immense promise, the broader adoption of VR in education requires overcoming significant challenges. High implementation costs, infrastructural constraints, and the need for specialized educator training are persistent barriers that must be addressed through strategic investments and multi-stakeholder collaboration. Ethical considerations, including data privacy and content integrity, also demand attention to ensure that VR is utilized responsibly and equitably. Long-term research and continuous innovation are essential to refining VR technologies and assessing their sustained impact on learning outcomes. As educational institutions strive to prepare students for an increasingly complex and interconnected world, VR stands as a pivotal tool to transform traditional pedagogies, equipping learners with the critical thinking and problem-solving skills necessary to thrive in a rapidly evolving global landscape.

LIMITATION

While this review highlights the potential of VR in enhancing cognitive skill development, several limitations must be acknowledged. The majority of the included studies focus on short-term outcomes, leaving a gap in understanding the long-term impact of VR-based learning on cognitive development. Additionally, the findings are drawn predominantly from studies conducted in developed regions with access to advanced technology and infrastructure, limiting generalizability to underprivileged or resource-constrained contexts. Furthermore, inconsistencies in VR content design and varying levels of educator expertise present challenges to establishing universal best practices for VR integration into curricula.

RECOMMENDATION

To fully leverage VR's potential in education, institutions should prioritize strategic initiatives that address financial, infrastructural, and training barriers. Partnerships with governments, technology providers, and non-profits can reduce costs and expand access to VR tools. Equally, investment in educator training programs tailored to both technical and pedagogical aspects is essential to maximize the impact of VR. Policymakers should advocate for inclusive VR designs that accommodate diverse learning needs, ensuring equity and accessibility. Finally, continued research on VR's long-term educational impact and interdisciplinary innovations, such as integrating VR with AI and AR, will be critical in shaping the future of education and enhancing cognitive skill development.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Acknowledgement

The authors acknowledge the invaluable support of academic and research institutions for providing access to resources and databases essential to this study. Appreciation is also extended to the contributors whose research has significantly informed the exploration of Virtual Reality's role in education. The constructive feedback from colleagues and reviewers has been instrumental in enhancing the quality of this work.

Declaration of Interest

The authors declare no conflict of interest.

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