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The Role of Virtual Reality in Education: Impact on Self-Efficacy, Cost, Cross-Cultural Learning, and Interaction

Cong Yan[1,2], Hasnah Binti Mohamed[1*]

[1]Universiti Teknologi Malaysia, Faculty of Educational Sciences and Technology, [2]XuanCheng School of Information Engineering

Email: hasnah-m@utm.my

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Abstract

Virtual Reality (VR) technology presents remarkable opportunities for learning, especially in strengthening students' belief in their academic self-efficacy. This study carries out a thorough analysis (30 existing papers) to evaluate the effect of VR across various educational settings, its advantages, and remaining challenges. The analysis indicates that the immersive and interactive qualities in VR settings considerably improve student participation and strengthen their confidence in their learning abilities. Nevertheless, there appears research gap that considers both interdisciplinary and cross-cultural perspectives when assessing VR's effectiveness. Besides, a limited academic focus can be observe with respect to the implementation of VR in environments with limited resources and the resulting impacts. To bridge these identified gaps, the present study puts forth a novel theoretical framework intended to optimize the incorporation of VR into educational methods and recommend differentiated approaches adapted to specific educational needs, the expansion of cross-cultural research, and the development of plans concerning economic viability and long-term consequences.

Keywords: Virtual Reality, Academic Self-Efficacy, Immersive Learning, Cost-Effectiveness, Cross-Cultural Research, Interactive Learning Environments

Introduction

Virtual Reality (VR) tools are transforming teaching approaches by creating digital learning spaces that stimulate student involvement and cognitive comprehension. The immersive nature of VR facilitates improved learner engagement as the virtual environment allows for the immediate visualization of core concepts. Research indicates that VR technology enhances the science course teaching proficiency by enabling interactive learning with virtual scientific tools. VR enhances learning effectiveness by offering students with opportunities for practical engagement in a virtual setting, minimizing external interruptions. The expansion of VR applications in education has been propelled by technological advancements, moving from rudimentary desktop systems to sophisticated wearable devices (Carruth, 2017). Current research on VR mainly focuses on higher education institutions, particularly in engineering science and healthcare disciplines, with less attention directed toward primary and secondary education (Lai & Cheong, 2022). The application of VR aids in improved student learning by enabling the practical application of observed and enacted knowledge, thereby strengthening constructivist and experiential teaching frameworks (Kim *et al.* 2022). The visually stimulating environment in VR cultivates the development of task-specific confidence in students through active learning engagements. Academic performance is enhanced through VR environments that facilitate social interaction, offer immediate feedback, and promote emotional investment in the learning process. While VR demonstrates established advantages, the effectiveness of these benefits is contingent upon the context and methodology of its application. While numerous students exhibit enhanced learning and increased participation in VR-based education, developed countries are experiencing slower rates of VR adoption. This slower adoption may be partially attributed to challenges such as content overload faced by educators (Luo *et al.* 2021). The effectiveness of VR is also influenced by regional factors and its alignment with local cultural norms (Jensen & Konradsen, 2018). A fundamental framework for applying VR in classrooms is essential to reduce existing financial and practical implementation disparities.

VR is able to facilitate learners in developing new skills through targeted cognitive processes. Integration of VR for verbal dialogue with avatars who offer immediate feedback also aids in enhancing the students' communication skills. In addition, VR environments assist in the development of emotional coping skills and cultivate greater collaboration among students (Lin *et al.* 2022). More recent literature concentrated on the educational effects of VR technology on different groups of students while longitudinally tracking the progress of their academic achievements (Hu-Au & Lee, 2017). Access to modern technology and advanced VR software bundles is primarily restricted to wealthy communities. Discrepancies in students' performance in VR learning environments indicate differences in students' responsiveness to various teaching approaches and their previous experience with technology, necessitating analysis in different contexts (Di Natale *et al.* 2020). Current VR systems are broadly categorized into two groups: stand-alone headsets – such as Oculus Quest – and PC-based systems such as HTC Vive (Elmqaddem, 2019). The low cost of independent VR hardware and its ease of use renders these devices particularly appealing for teaching in underfunded schools (Kolecki *et al.* 2022). The devices are readily integrated into educational settings as they do not require additional computers, tracking cameras, or sophisticated technical skills. While systems that connect to PCs offer graphical quality and user immersion that are superior, the expenses and intricacies involved in setting them up are still significantly high (Radianti *et al.* 2020). VR platforms designed for specific medical and engineering purposes are effective, but tend to exceed the spending limits of many underfunded schools (EdTech Magazine, 2024). Standalone VR headsets enable educational facilities to satisfy performance criteria while adhering to fiscal limitations (Liu *et al.* 2023). PC-connected systems yield exceptional results when executing complex applications (Jensen & Konradsen, 2018). The disparity in spending highlights the need to address the unequal provision of VR learning technologies to students regardless of their economic status and background (Pottle, 2019). This review outlines VR's ability to cultivate self-esteem and educational achievement while addressing its principal constraints (McLean & Foa, 2022). Successful integration necessitates resolutions for financial burdens, respect for cultural diversity, and consideration of future effects on students. Research teams should now determine how to make VR more cost-effective and appraise the educational benefits it can offer across various student populations over time (Rojas-Sánchez *et al.* 2023). Delicate incorporation of VR in education opens unexplored teaching methods, elevating students' belief in their capabilities regardless of the context in which they are learning.

Literature Review

Evolution and Adoption of VR in Education

VR's introduction into educational fields began during the 1960s with rudimentary virtual environment platforms. Due to critical technological advancements that enhanced usability, VR equipment is now obtainable at reasonable prices for educational and commercial applications (Lee *et al.* 2024). VR generates dynamic, authentic environments that promote enhanced student learning, establishing its significance in education (Kaddoura & Al Husseiny, 2023). Current VR utilization is still restricted due to its pricing and operational complexities that affect both users and administrators (Dhar *et al.* 2023). The recent decade has witnessed a surge in VR applications in adult and higher education, particularly for secure medical and engineering training simulations (Komljenovic, 2022). The field of VR in education has progressed significantly since the recent technological surge, with market analysis projecting the "Metaverse Education" sector to reach US $3.7 billion by 2025 (Statista, 2025a). Projections indicate a major market expansion at a CAGR of 46.60%, reaching $24.7 billion by 2030. The United States currently represents the largest market, expected to reach US $1.4 billion in 2025. Subscriber numbers are predicted to increase to 104.6 million by 2030, with market penetration rising from 0.5% in 2025 to 105.7% by 2030, driving the evolution of cutting-edge immersive learning platforms (Statista, 2025a). VR environments enable students to safely practice complex procedures, reducing the risks associated with conventional practical training. In their respective curricula, medical students employ VR to simulate surgical operations, and engineering students utilize VR to manipulate virtual machinery (Pregowska *et al.* 2022). Despite limited VR adoption in contemporary educational institutions, this technology holds considerable promise for captivating young learners and enhancing their motivation through interactive educational possibilities.

Benefits and Challenges of VR for Young Learners

Evidence suggests that VR offers particular advantages for young students, especially those with learning differences. In this medium, students acquire practical proficiencies applicable beyond the classroom setting. Numerous researchers express reservations regarding the analysis of VR's safety implications for children, citing potential negative effects on their physical and psychological well-being (Marougkas *et al.* 2023). To ensure VR's suitability for young users, the VR industry must address issues relevant to cybersickness and the negative effects of prolonged screen exposure. VR technology demonstrates greater educational effectiveness in developed countries, as effective implementation in developing countries is contingent upon enhanced educational infrastructure (Huang *et al.* 2019). The educational VR applications in developing regions faces numerous impediments, ranging from inadequate electronic infrastructure to restricted access to qualified professionals (Lee & Wong, 2008). Future research should extend beyond short-term tests to identify the long-term retention of VR-acquired knowledge as well as its impact on academic performance (Wu *et al.* 2022).

The Utilization of VR With Ethical Considerations

Privacy Concerns

VR platforms collect substantial information regarding user cognitive processes, emotional states, and physiological well-being, which presents significant challenges to personal privacy.

During VR interactions, headsets are capable of monitoring both ocular movements and neurological signals (Merchant *et al.* 2014). Children's usage of VR on a regular basis introduces higher risks to data protection, particularly in education (Dhimolea *et al.* 2022). Educational institutions must establish robust protocols for data security, including the anonymization of sensitive personal details and the clearly defined procedures for user data acquisition and processing (Kamińska *et al.* 2019). To protect private information, it is essential that students and their guardians receive comprehensive information about data collection practices, enabling them to withhold authorization for the collection of non-essential data.

Psychological Impact of Prolonged VR Exposure

Prolonged engagement with VR can induce a sense of unease, often coupled with symptoms of cybersickness, such as visual disturbances, nausea, and headaches. Younger internet users, specifically those under the age of 18, are more susceptible to developing significant side effects, including visual impairment, equilibrium difficulties, and challenges in perceiving the physical world (Pellas *et al.* 2021). While VR experiences can elicit strong affective responses in learners, these reactions can become excessively intense when individuals are subjected to emotionally charged simulations (Zhao *et al.* 2022). Educators should adhere to predetermined time allocations for student VR utilization and curate content to align with age-appropriate guidelines (Chavez & Bayona, 2018). Based on recommendations from the American Academy of Pediatrics, it is advisable to limit children's daily VR exposure to a maximum of two hours of screen time (González-Zamar & Abad-Segura, 2020).

Over-Reliance on Technology

The increased application of VR and other digital tools in education is worrisome for teachers due to the possible disregard for traditional teaching approaches. Despite its applications, VR cannot supplant basic practices such as face-to-face interactions and problem-solving opportunities with students (Al Farsi *et al.* 2021). The excessive application of VR leads students to consume information passively, rather than actively engaging with material (Fitria, 2023). Educators must ensure that essential teaching aims and objectives are accomplished through designed plans that integrate VR lessons into their plans (Alhalabi, 2016). Training for teachers requires an understanding of how to integrate VR technology with conventional teaching methods and student interactions that foster skill and cognitive development (Wang *et al.* 2018).

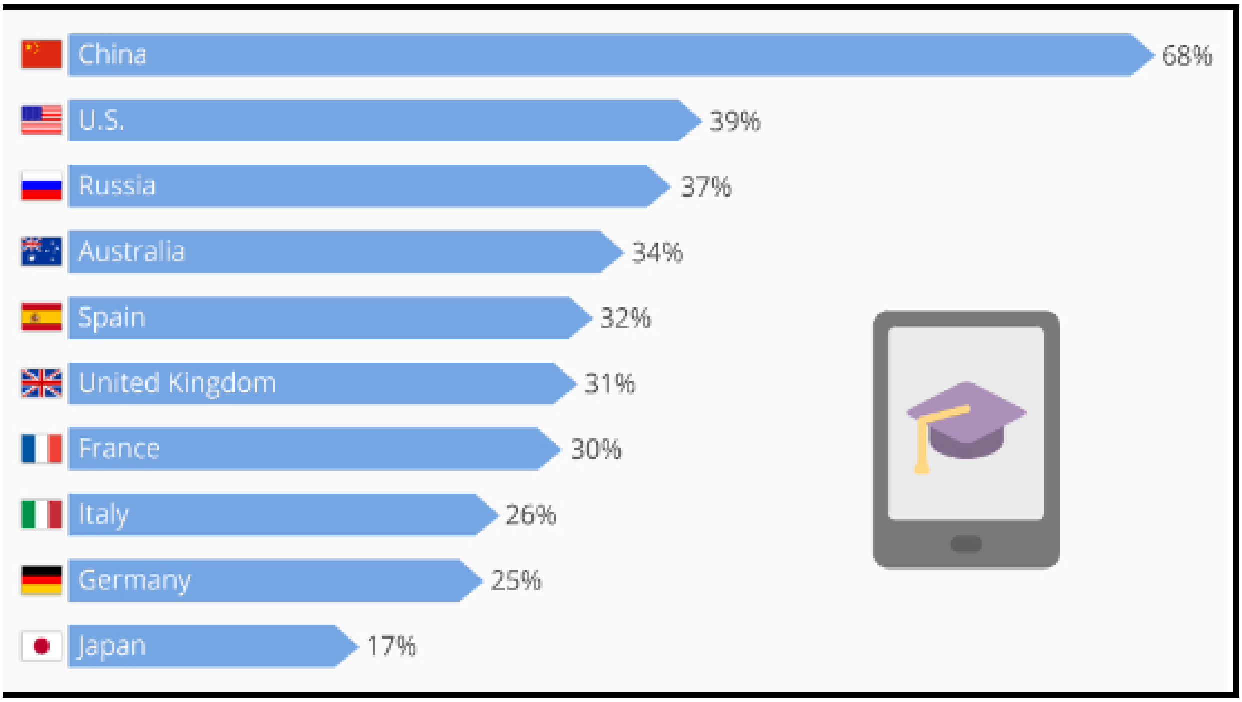

Figure 1: Education Struggling to Keep up with Digital Advances
(Source: Statista, 2025 b)

As demonstrated in the preceding figure, China has a commanding lead in preparing its population for a rapidly evolving digital society. In a survey conducted across ten countries, approximately one-third of respondents expressed satisfaction with their formal education's preparation for the technological demands of contemporary life; this sentiment was significantly higher in China (68%), compared to the United States (39%) and Russia (37%) (Statista, 2025b); whereas, Japan, identified as exhibiting the least favorable outcomes, appears to possess an educational structure that has not adequately adapted to technological advancements, with only 17% of respondents expressing positive views in this regard (Statista, 2025b).

Mitigating Challenges Through Responsible Use
The ethical development of VR tools necessitates the formulation of verified principles to guide both the creation and deployment of VR systems. Educational institutions must prioritize user privacy as a fundamental concern, alongside the selection of content that aligns with the developmental stage of each student and the provision of resources for teachers to effectively manage VR utilization (Marougkas *et al.* 2023). Administrators in educational settings should establish clear guidelines concerning the types of student data that are monitored and the permissible duration of student engagement with VR, to ensure the protection of learners (Hu-Au & Lee, 2017). Considering that educational VR achieves optimal effectiveness when integrated with established classroom methodologies, it is crucial for teachers to exercise control over student technology usage. VR becomes a beneficial tool for learners when educators employ it reasonably for teaching and supportive purposes.

Method

This analysis employed a selection of 30 existing academic publications from diverse academic journals with inclusive and exclusive criteria to appraise the educational outcomes and functions of VR. The inclusion criteria consisted of English language peer-reviewed papers related to educational VR implementations in the timeframe of 2017 to 2024. The derived data was then analyzed with thematic analysis methods. Compliance was maintained with ethical considerations, including the avoidance of data misrepresentation, proper attribution to original authors, and prevention of data manipulation.

Main Findings

VR technology has achieved dissemination across primary, secondary, and tertiary levels of educational systems. Analysis of 30 high-impact research articles from the period 2014-2023 indicates that researchers primarily explore the learning advantages of VR and its capacity to integrate various disciplines (Gattullo *et al.* 2022). The preponderance of available research concentrates on the educational benefits of VR, while comparatively less attention is devoted to the practical costs, associated cultural factors, and the long-term consequences of VR implementation in learning environments (Pande *et al.* 2021).

VR in Education: Themes and Trends

Research findings suggest that VR possesses the capacity to cultivate engaging educational environments that are advantageous for students across disciplines such as science, engineering, medical education, and language teaching (Marougkas *et al.* 2023). Contemporary analyses indicate that VR enhances learner engagement and student motivation, consistent with prior studies that demonstrated VR's effectiveness across diverse learning practices (Kaddoura & Al Husseiny, 2023). However, considerable uncertainty persists regarding the long-term effects of VR on education and the factors contributing to its high expense in resource-constrained settings.

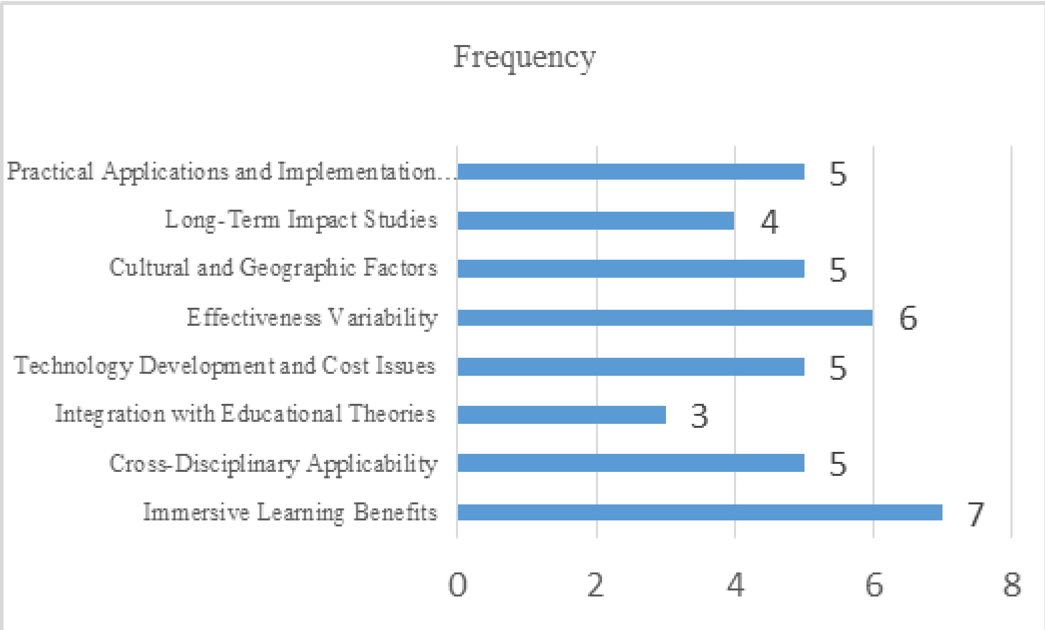

Figure 2. The Summary of Literature Based on Themes (Source: Self-Created Based on the Selected papers)

Figure 2 illustrates that studies primarily probed the immersive potential of VR across various subjects, yet face challenges such as financial limitations and the need for sustained research efforts. To facilitate more widespread and effective integration of VR in education, thus the field should address these existing challenges.

Self-Efficacy: Definition and Relevance

An individual's perceived competence in managing academic tasks significantly affects their educational outcomes. Greater self-belief cultivates increased curiosity and resilience, leading to greater achievement (Kamińska *et al.* 2023). According to Albert Bandura, self-efficacy governs the level of academic dedication and perseverance demonstrated by students in pursuit of their learning objectives. Learners who possess confidence in their capabilities engage more deeply with learning materials and persist in addressing challenging assignments (Kaimara *et al.* 2022). Extending beyond academic environment, self-efficacy impacts an individual's health-related behaviors, both physical and emotional, and shapes their vocational choices (Al-Ansi *et al.* 2023). Individuals with robust self-efficacy tend to adhere to healthy routines and effectively utilize medical advice, exhibiting enhanced recovery from setbacks (Qiu *et al.* 2023). In professional settings, employees exhibiting strong self-efficacy readily adapt to novel technologies, undertake demanding responsibilities, and frequently assume leadership roles in teams (Korkmaz & Morali, 2022).

Mechanisms to Enhance Self-Efficacy

VR enhances learning and skill development by allowing users to engage with dynamic digital environments, enabling hands-on practice. In virtual science laboratories, students can conduct experiments and interpret data, thereby cultivating increased self-confidence in their scientific abilities (Pregowska *et al.* 2022). VR's simulation platforms and interactive tools cultivate students' belief in their personal capabilities, enhancing team cohesion and commitment, which enhances their educational performance (Frost *et al.* 2022).
Bandura identified four fundamental sources of self-efficacy:
Mastery Experiences: Successful performance in progressively challenging tasks strengthens confidence levels. Educational programs should be designed to incorporate tasks that allow students to achieve increasing levels of accomplishment over time (Huang, 2019).
Vicarious Experiences: Observing peers or mentors achieving objectives cultivates an individual's conviction in their own potential, particularly when the observed individuals are perceived as relatable.
Verbal Persuasion: Credible encouragement from educators and supervisors in professional settings assists individuals in maintaining resilience during periods of difficulty (Kim & Lee, 2022).
Emotional and Physiological States: Positive emotional states enhance an individual's belief in their abilities, whereas stress and anxiety can undermine self-confidence (Pregowska *et al.* 2022). Healthcare providers can facilitate individuals improve coping mechanisms by cultivating a sense of calm and encouraging the practice of relaxation methods (Pirker & Dengel, 2021).

Professional development utilizes these learning methods to support team members in enhancing their self-efficacy. Educators contribute to student self-efficacy development by promoting collaborative teamwork, offering constructive guidance and feedback, and facilitating personalized reflection (Reeves *et al.* 2022).

Addressing Gaps and Expanding Research

The research (Villena-Taranilla *et al.* 2022) argued that even with VR's integration with teaching methods and the student self-efficacy, challenges remain regarding cost and impact over time for different populations that need to be explored. It is verified that the development of such platforms that are VR-compatible and balanced with respect to expenditures, accessibility, and performance cultivates the use of VR throughout education levels (Billingsley *et al.* 2019). Due to the individual and cultural aspects, personalized approaches assist learners throughout all stages of education with VR through diverse strategies. VR programs directed toward cultivating self-confidence among students positively influence their academic performance and success both socially and professionally. The design of effective strategies and thorough execution may enable VR to become a fully actualized educational asset.

Current Cases of Virtual Reality Applications

Case 1: Application in High School Students

Studies suggest VR technology cultivates scientific self-efficacy in high school learners. One study with 66 participants divided students into two groups for the comparative study. Pre- and post-self-efficacy tests were administered to both groups pre- and post-interaction with a VR science program (Lege & Bonner, 2020). Findings demonstrated students' self-belief was greater after participating in VR lessons based on various models and procedures, particularly when suffering from scientific principles and executing experimental procedures (Nissim & Weissblueth, 2017). However, the confined sample size may not be generalizable to broader contexts. VR technology offers learners tools for enhancing learning using controlled environments where theories can be represented and tested from various perspectives in science (Nissim & Weissblueth, 2017). This VR technology facilitates learners' understanding of molecular structures and works effectively. Additionally, students can improve understanding of history through virtual simulations by exploring ancient civilizations, similar to tourism (Gan *et al.* 2023). VR technology cultivates enriched historical learning experiences by offering students avenues for learning in relevant historical structures and artifacts. Moreover, students can immerse themselves in fictional stories strengthening connection by granting them the opportunity to interact with characters and settings from books (Medium, 2024). In physical education, VR presents possibilities for training in sports for learners regardless of physical spaces and equipment constraints that increased participation among students (Van Mechelen *et al.* 2023). Secondary education institutions are increasingly adopting VR technology to enhance competencies and personalize learning approaches as these technologies develop.

Case 2: Application in Teacher Training

Teachers are utilizing VR systems as these platforms facilitate the cultivation of teaching proficiencies in simulated environments. Merchant et al. confirmed trainee teachers' engagement with VR contributes to teaching capabilities while cultivating creativity and strengthening problem-solving aptitude (Merchant *et al.* 2014). This interaction allows trainees to build confidence as they optimize skills through practice in simulated classroom situations. Though the value of VR in enhancing student learning is documented, educators require professional development programs to incorporate VR in classrooms (Zheleva *et al.* 2024). Evidence suggests teachers often lack technology training needed to use VR in classrooms. Merchant emphasizes teachers need technological training on these systems to leverage the potential of VR technologies and increase student participation (Merchant *et al.* 2014). Professional development strategies can address this deficiency (Wang & Hu, 2022). Empowering teachers with professional workshops, training, and certification sessions employing VR enhance teaching practice that can facilitate development of teachers in applying VR in educational settings (Fernandez, 2017). Receiving training and resources, teachers can leverage VR for educational practices.

Case 3: Application in Medical Education

Medical educational institutions are now employing VR, enabling students to exercise surgical methods and clinical skillsets in a safe setting. VR immerses students in an operating theater and allows them to practice suturing wounds and administering injections (Kavanagh *et al.* 2017). Research has presented that students trained in hands-on teaching methods become more proficient and make fewer errors; in addition, studies demonstrate that students learn with greater effeicacy and confidence. With VR, students can repeatedly perform the procedures, such as cardiac and neurosurgery, without the risks of treating a live patient as practice (Uruthiralingam & Rea, 2020). Students can receive immediate feedback with VR systems incorporating feedback mechanisms, allowing them to learn synchronously in the virtual environment (Zhang & Wang, 2021). Moreover, VR technology allows students to develop effective strategies for interacting with patients while teaching them crucial interpersonal competencies such as emotional intelligence and cross-cultural sensitivity (Radianti *et al.* 2020). The quality of patient care is expected to improve with the integration of collaborative training in VR environments (Monteiro *et al.* 2024). While VR systems incur a significant monetary expense, their benefits in medical training are significantly persuasive and worthy of attention by educational institutions seeking to cultivate skilled healthcare professionals.

Case 4: Higher Education: Stanford University's Virtual Reality Lab

Stanford University Medical School integrates HTC Vive and Oculus Rift VR technologies into its curriculum to facilitate the instruction of surgical procedures. Learners gain operational expertise through the performance of tasks such as coronary artery bypass grafting and heart valve repair in a three-dimensional replication of an operating theatre, which offers haptic feedback during training exercises. Research findings suggest that VR-based learning produces surgical students who achieve superior speed and accuracy in their operations when compared to their counterparts trained through traditional classroom methods (Stanford Medicine, 2024). Students develop enhanced skills through practice as VR sessions obviate the need for human subjects or physical equipment during skill acquisition. VR-based education mitigates psychological pressure, allowing students to master complex procedures thoroughly without the potential consequences of failure in real-world clinical scenarios. Beyond cardiology, Stanford University is realizing the benefits of VR applications in disciplines such as neurology and orthopaedic surgery (Stanford Medicine, 2024). Through its utilization of immersive VR training methods, the university demonstrates the potential of higher education to equip students with optimal approaches to managing medical challenges utilizing VR technologies.

Case 5: K-12 Education: McKinley Technology High School

McKinley Technology High School, situated in Washington D.C., incorporates VR into its STEM curriculum to cultivate an active learning environment for its students. The school collaborates with Verizon Innovative Learning to offer students with access to Google Expeditions, facilitating virtual field trips to augment learning experiences. Student cohorts, such as history classes, are able to explore ancient archaeological sites, while biology students can study natural marine environments through underwater simulations (EdTech Magazine, 2024). The program has resulted in higher student engagement in their studies and improved academic performance in science and history. Student agency in learning is amplified through VR engagement, nurturing innate curiosity about the world (U.S. News, 2024). VR empowers educators to create enriched learning experiences by granting students access to authentic resources and delivering exploratory lessons through interactive virtual environments (Hamilton *et al.* 2021). The successful implementation of VR at McKinley School has inspired other local educational institutions to adopt similar programs in their own settings (Arici & Yildiz, 2023). This technological approach exemplifies its capacity to transform teaching methodologies across diverse subject areas in the K-12 educational spectrum.

Case 6: Vocational Training: Volkswagen's Mechanic Training
Volkswagen employs VR for the training of apprentices in automotive maintenance procedures. Trainees utilize HTC Vive headsets to develop proficiency in engine repair, brake system diagnostics, and electronics troubleshooting through interactive virtual vehicle models. The system, which eliminates the requirement for physical vehicles, reduces operational costs and minimizes logistical complexities associated with traditional training. The VR training program enables apprentices to practice procedures until they attain mastery, thereby cultivating self-assuredness in their technical abilities (Medium, 2024). Trainees are offered with opportunities to engage with uncommon repair scenarios that extend beyond the scope of their standard classroom curriculum. Volkswagen has realized reductions in training expenditures and improvements in trainee performance as a consequence of its successful VR-based educational system. Following Volkswagen's positive outcomes with VR, other automotive manufacturers are exploring the adoption of similar methodologies (Medium, 2024). VR delivers advanced training capabilities at decreased expenses, effectively developing technical competencies in industries reliant on practical, hands-on learning approaches.

The Application of Virtual Reality Across Educational Scenarios
The integration of VR in educational settings demonstrates a spectrum of outcomes across various learning levels, reflected by various advantages and challenges.

K-12 Education
Across K-12 educational levels, VR is being implemented in STEM disciplines to cultivate enhanced student self-confidence and motivation. Students can safely conduct practical experiments through online virtual laboratories, which aids in the development of both practical skills and self-efficacy. Virtual tools empower students to manipulate equipment and analyze experimental data by modifying laboratory parameters in the simulated environment (Pirker & Dengel, 2021). VR facilitates direct student interaction with scientific concepts, such as the structure of DNA and the dynamics of ecosystems, through engaging virtual experiences (Huang & Yang, 2022). In the domain of mathematics, VR transforms abstract concepts into tangible and readily understandable experiences, enabling students to manipulate geometric shapes and mathematical models in a virtual space (Wang *et al.* 2018). This approach contributes to improved student understanding and appreciation of the subject

matter (Johnston *et al.* 2018). VR empowers students to explore digitally reconstructed historical societies and witness critical moments from the past, rendering historical learning more engaging than traditional text-based approaches. Moreover, VR environments facilitate language skill development through practical interactions in simulated realities (Leung *et al.* 2018). For instance, students can practice ordering food in French while navigating virtual Spanish streets in immersive VR experiences. VR's interactive training sessions cater to diverse learning styles, including visual, kinaesthetic, and neurodiverse learners, promoting enhanced focus and engagement.

Higher Education

VR tools are most commonly observed in university programs related to medicine, engineering, and architecture. Through VR utilization, students gain access to detailed simulations for the acquisition of practical skills in a risk-free environment, reducing the potential for real-world harm. Medical students employ virtual surgical simulations to enhance both their self-belief and performance ratings (Al-Ansi *et al.* 2023). Students in engineering and architecture benefit from VR-enhanced 3D modeling experiences, improving their problem-solving capabilities and understanding of challenging structures. VR tools also assist pre-service teachers in learning classroom management and teaching methods through realistic simulations prior to entering professional practice (Solak & Cakir, 2016). This training paradigm supports teacher skill development and cultivates increased confidence in their teaching abilities.

General Advantages and Challenges

The examination of research findings indicates that VR offers valuable educational tools that enable students to explore simulated environments and demonstrate effectiveness across a range of applications. Despite the established advantages of VR documented by researchers, further analyses are warranted to address specific areas of concern and optimize implementation.

Cultural Variability in the Implementation and Effectiveness of VR in Education

The application of educational VR technology exhibits significant difference across global educational systems. For successful integration of VR tools in an educational framework, consideration must be given to several factors: societal perceptions of technology, culturally influenced learning objectives, and the alignment of learning experience accessibility with student educational goals (Jumani *et al.* 2022).

Cultural Perceptions of Technology in VR Education

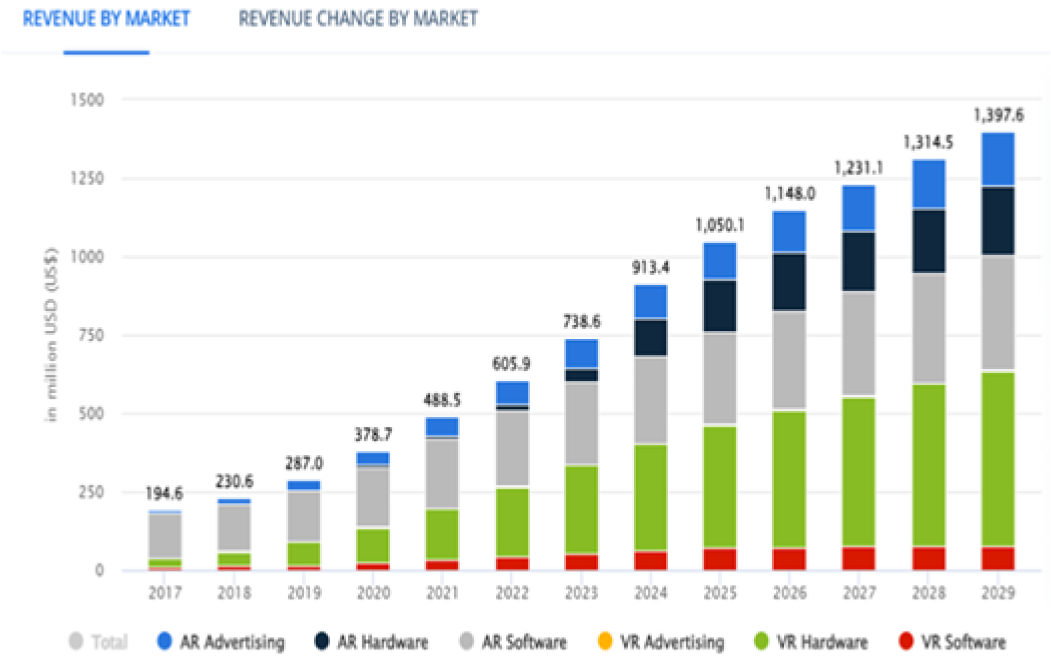

Figure 3. Forecasted Revenue Trend for AR and VR Markets (Source:Panganiban et al. 2024)

Societal attitudes towards technology significantly affect the incorporation of VR programs into educational systems. countries such as South Korea and Japan are at the forefront of VR implementation, largely attributable to their robust endorsement of innovation and digital evolution. In South Korea, over 40% of educational institutions are integrating VR-based learning, particularly in STEM disciplines, a trend cultivated by national strategies aimed at technological integration (U.S. News, 2024). The markets for both VR hardware and software demonstrate continuous expansion, driven by increasing investments from individuals and commercial enterprises (Wang & Hu, 2022). In classrooms settings, VR is employed to construct realistic laboratory simulations and historical environments to enhance knowledge retention among students when compared to conventional learning methods. Nevertheless, in numerous communities, there remains a degree of concern regarding the adoption of immersive technologies (Chai et al. 2022). Despite observable increases in the acceptance of digital teaching methodologies in countries including India and Brazil, reluctance towards VR tools remains evident (Gonaygunta et al. 2023). In rural Indian educational establishments, conventional teaching methodologies, such as rote memorization, prevail, as VR technology is tested in a mere 10% of these institutions (Pellas et al. 2021). Concerns exist regarding the effectiveness of immersive technological tools in classrooms from a lack of complete confidence in technology and anxieties about potential disruptions to established educational practices. The expanding markets for augmented and VR suggest a promising future for these technologies in the field of education (Bower & Jong, 2020). Successful integration of VR tools necessitates tailoring them to diverse educational requirements and addressing cultural barriers to achieve comprehensive utilization of VR technology in global educational institutions.

Comfort with Immersive Technology

The selection of VR technology by educational bodies is contingent upon the perceived comfort levels of users in these virtual environments. In North America and Canada, where experiential learning methodologies are prevalent, 60% of schools are opting for VR technology to enhance student engagement (Fiani et al. 2020); whereas, in Japan, a preference for instructor-led teaching results in the majority of schools maintaining traditional educational methods (Di Natale et al. 2020). Concerns about potential decreases in student discipline attributed to VR, coupled with resistance to novel learning tools, highlight the necessity for experts to align VR technology with established teaching practices across varied educational settings (Chun et al. 2022).

Comparative Analysis of VR Adoption Rates

The most prominent rates of VR educational tool adoption in academic environments are observed in regions such as North America and Europe. This trend is facilitated by official endorsements for interactive technological resources. Projections indicate that the North American VR education sector is expected to experience a business growth of 35% (2022 ~ 2027) (Zheleva et al. 2024). In comparison, the availability of VR technology remains significantly limited in sub-Saharan African schools due to inadequate resources and deficient network infrastructures, which impede accessibility (Chen et al. 2022). Pilot initiatives in Kenya and South Africa, supported by non-governmental organizations and technology firms, offer evidence of VR education's potential in STEM disciplines (Al-Ansi et al. 2023). Southeast Asia presents a varied situation. Singaporean educational institutions demonstrate regional leadership with a 30% VR adoption rate, a consequence of government-supported programs. This contrasts with Indonesia and the Philippines, where ongoing challenges related to accessibility hinder the broader implementation of VR (Uruthiralingam & Rea, 2020).

The Role of Governmental and Institutional Support

The future development of VR education is closely associated with the provision of funding from both governmental and organizational bodies. Globally, China is unique in its substantive financial commitment to VR educational applications to stimulate advancements in technology. Driven by effective governmental support, VR-based learning environments are scheduled for integration into Chinese high schools starting in 2025; whereas, in Brazil and Mexico, limited governmental backing impedes the widespread introduction of VR into mainstream public education, resulting in reliance on external funding sources (Japan Times, 2024). Societies that prioritize conventional educational philosophies often exhibit opposition to VR adoption owing to concerns that it might disrupt deeply rooted learning methods. A significant barrier to VR accessibility for numerous individuals is its associated cost (Marrahi-Gomez & Belda-Medina, 2022). The Oculus Quest headset, priced between $300 and $500, offers a wireless VR experience without supplementary setup expenditures, thus presenting a more economically viable option for educational institutions with constrained budgets (Shim, 2023). Wireless mobile platforms enable the deployment of VR technology in remote or resource-limited locations, thus minimizing installation complexities (Monteiro et al. 2024). However, standalone VR devices lack the processing capability required for simulations essential for advanced medical and engineering applications. PC-tethered systems, such as the HTC Vive, offer enhanced graphic fidelity and improved processing speed relative to standalone alternatives (Uruthiralingam & Rea, 2020). These systems necessitate financial outlays ranging from $1,000 to $2,500. Additionally, they require dependable high-speed network connectivity and a consistent power supply (Faria & Miranda, 2024). While these systems are suitable for well-funded educational organizations, they remain impractical for schools in developing countries where fundamental technological resources are scarce (Villena Taranilla et al. 2022).

Figure 4. VR System in Educational Purpose (Source:ixrlabs, 2024)

The dependence on PC-linked standalone VR systems presents challenges for schools with restricted financial resources in implementing VR training. Basic VR systems expand the potential for immersive learning experiences in a greater number of educational institutions globally. This is particularly relevant even when these institutions operate under budgetary constraints (Durukan et al. 2020). Addressing the cost implications of PC-tethered systems is crucial to ensure equitable access for all (Huang & Yang, 2022). Future advancements in VR system development should prioritize cost reduction to facilitate the deployment of sophisticated simulation setups across a broader range of schools (Nolte et al. 2024). While PC-tethered systems are accessible to more affluent school districts, standalone VR solutions contribute to reducing educational disparities for institutions with limited funding. Collaboration between governmental bodies and educational organizations is essential as VR technology progresses to ensure accessibility for students irrespective of system expenses (Fabris et al. 2019). Initiatives should be directed toward reducing VR costs to enable students worldwide, regardless of socioeconomic status, to benefit from enhanced educational opportunities (Faria & Miranda, 2024). For successful widespread adoption, focused investments in innovative products, combined with equitable policies that promote universal access to VR technology, are necessary.

Table 1
Conceptual Framework

Component	Multi-Level Model	Cross-Cultural Research	Cost-Effect Analysis
Description	Stage-specific VR use	VR in diverse contexts	Cost and impact studies
Challenges	Varied impact, ethics	Cultural differences	High costs, lack of data
Focus	Tailored applications	Expand global studies	Assess long-term feasibility

Discussion

VR interactive learning environments contribute to the enhancement of academic self-efficacy among students across diverse learning modalities (Suri et al. 2023). Engaging students with realistic virtual simulations significantly improves academic performance and cultivates a higher sense of academic competence (Parmaxi, 2023). While this learning methods exhibits utility, further analysis is required to comprehensively understand its full potential and associated limitations (Sırakaya & Alsancak Sırakaya, 2022). Continued research into the application of VR in education should focus on its effects on students across varying educational levels and diverse cultural backgrounds. Additionally, longitudinal studies are needed to assess the sustained impact of VR on student confidence (Tiwari et al. 2023).

Addressing Educational Contexts and Cultural Variability

While extant research on VR applications primarily concentrates on STEM subjects, analyses indicate the effectiveness of these methodologies extends to disciplines including language acquisition, social sciences, and artistic fields. Research findings suggest that the educational benefits of VR are modulated by the specific educational setting, whether K-12 or higher education, and also by geographical location. Societies that emphasize experiential learning as a standard learning method tend to readily embrace VR technologies (Jensen & Konradsen, 2018); whereas, resistance to VR implementation is more frequently encountered in educational settings where conventional rote learning methodologies are prioritized over experience-based learning. Comprehensive reports detailing the relationship between cultural norms, educational systems, and VR adoption are necessary. Such reports would enable the design of VR training programs that are appropriately for individual student needs and diverse learning environments (Yildirim et al. 2018).

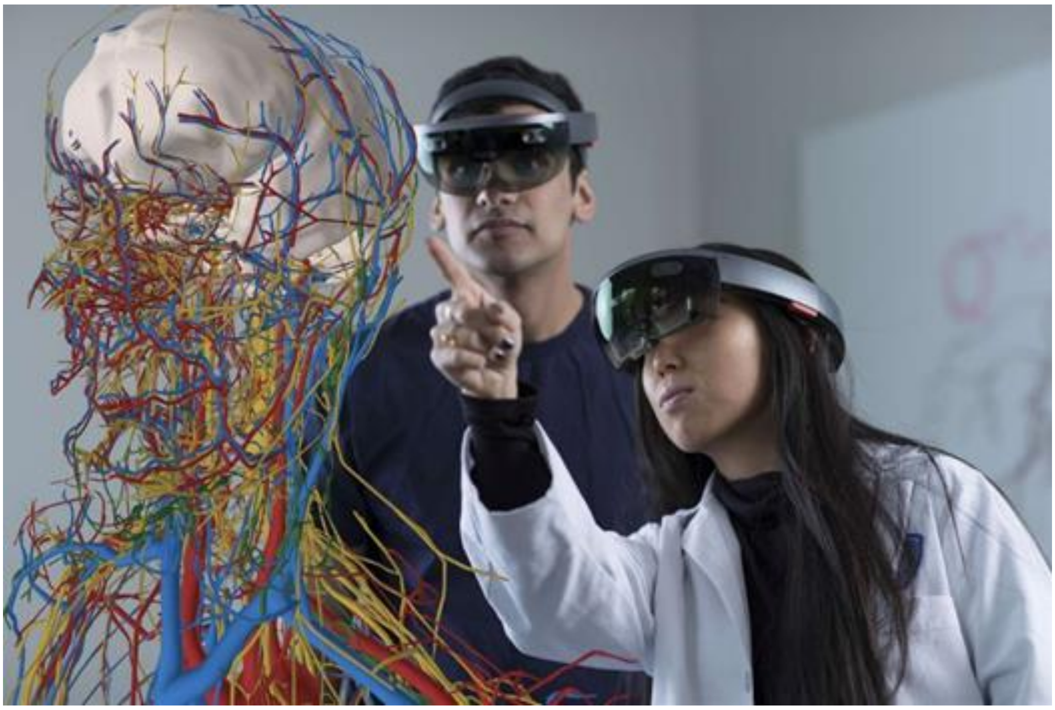

Figure 5. AR Application in Biology Classes (Source:Microsoft, 2024)

VR educational approaches produce superior outcomes when contrasted with alternative educational modalities largely due to their capacity to generate authentic learning scenarios.

VR-based education supplants outdated textbook and audio-centric methodologies by immersing students in practical, real-world simulations for target language practice (Leung *et al.* 2018). Platforms such as MondlyVR and AltspaceVR facilitate language learning by enabling students to virtually interact in digital environments resembling restaurants and cityscapes (Panganiban *et al.* 2024). Collaborative interactions among learners in VR environments promote accelerated development of communication proficiencies. This is further enhanced by the provision of immediate feedback in the system (Sirvermez & Baltaci, 2023). Researchers are employing VR to recreate historical occurrences, facilitate community-based research, and analyze human behavioral patterns.

Virtual field trips, such as those offered by TimeLooper, enable students to explore historical locations virtually, thereby delivering memorable history lessons. Sociology students utilize virtual spaces to appraise group dynamics and analyze interpersonal relationships before addressing broader societal issues (Freina & Ott, 2015). Psychology students engage with VR content that simulates psychological behaviors and offers teachings on effective therapeutic interventions, notably in exposure therapy for phobias and Post-Traumatic Stress Disorder (Karale *et al.* 2023). Learning through VR engagement surpasses traditional classroom-based teaching methods. Research indicates that students utilizing VR demonstrate a 25% improvement in knowledge acquisition (Faria & Miranda, 2024).

Figure 6. Application of Mixed Reality(Source:hitechlab, 2024)

The arts also experience enhancement through VR technology. Learning tools such as Tilt Brush and Oculus Medium empower visual arts students to create three-dimensional artwork that cultivates robust spatial reasoning and creative aptitude. Students in performing arts disciplines can optimize their stagecraft skills in digital theatrical environments offered by StageCraft. Music students can utilize virtual spaces such as Virtuoso to learn tools and compose musical pieces (Won *et al.* 2023). Google Arts & Culture enables students to virtually visit renowned museums from their homes and explore artistic creations from across the globe. VR art applications unlock novel creative avenues for students, transcending the confines of conventional classroom settings.

The Need for Longitudinal Studies

Current literature work indicates that VR applications can enhance student engagement and learning outcomes in immediate timeframes. However, an absence of research exists concerning the sustained impact of VR implementation. It is crucial for ongoing studies to determine the longitudinal effects of VR on cognitive development, specifically how students retain information and then apply acquired knowledge in real-world scenarios. Existing evidence implies that VR technology possesses the capability to facilitate the development of novel cognitive proficiencies. By engaging their sensorium to explore and process spatial data, students can cultivate critical thinking capabilities. Scientific literature suggests that learning experiences utilizing VR yield enhanced spatial reasoning and cognitive frameworks, particularly for students in STEM disciplines. Much of the existing body of research documents the immediate cognitive impacts of VR, while a paucity of data remains regarding the durability of these cognitive enhancements (Qiu *et al.* 2023). Experts must conduct analyses into the protracted influence of VR on students' cognitive capacities as they progress through their education and professional careers. Evidence suggests that VR has demonstrated superior effectiveness compared to conventional teaching methodologies in aiding recall. Prior studies substantiate that VR-based learning methods facilitate improved information retention in students when contrasted with traditional teaching paradigms. Findings indicate a significant difference in long-term retention rates: students learnt through VR retained approximately 80% of lesson content after one year, whereas students learning from textbooks exhibited a retention rate of only 50%. It is hypothesized by research that VR education promotes superior memory retention due to the immersive engagement with virtual content. Future research should concentrate on evaluating the long-term academic performance of students exposed to VR, particularly in the domains of mathematics and scientific disciplines (Liu *et al.* 2022). The value of VR training is contingent upon the extent to which students can transfer skills beyond specific virtual environments, especially in contexts for professional development and advanced education. Educational analyses have demonstrated that students receiving VR-based learning acquire competencies that translate more effectively to real-world tasks compared to students receiving traditional education. Learners trained in surgical procedures utilizing VR exhibited a 30% improvement in effectiveness and accuracy. Continued research should explore the persistence of VR-acquired skills post-training and their utility in professional settings. Future research will be instrumental in determining the utility of VR in education.

Emerging Trends in VR, AR, and MR

The growing use of VR in education increases interest in AR and MR technologies. These tools function collaboratively to develop new means of facilitating learning. Students have the capability to interact with real and virtual elements and information, creating enriched learning experiences. For instance, biological learners can now see vivid images of anatomical structures with Google Perspective. Students can also use Merge Cube to interact with 3D models of planets as well as historical artifacts. FotonVR (2024) states that these interactive learning tools capture the attention of students and help them better understand the learning content. Users in MR environments experience blended reality, meaning they can interact with both real-world and computer-generated objects. Medical students in higher learning institutions are utilizing Microsoft HoloLens for anatomical studies as the device enables the projection of 3-D models of anatomical components onto current anatomical systems in classroom settings during active teaching sessions. In addition, students are offered with 3D models in different scientific subjects such as biology, chemistry, and engineering to utilize and engage with on the zSpace platform, which increases their participation in learning activities. Mixed reality technology integration in education contributes to enhancing student performance by 30% along with increased participation in classroom settings. The integration of Virtual and Augmented Reality teaching methods creates a comprehensive system. These methods (Bower & Jong, 2020) work in synergy to address the diverse educational needs of students. For instance, AR can render a biological specimen with enhanced visibility while MR enables the manipulation of its three-dimensional model and VR allows users to explore virtually. These collective technologies may cultivate an enhanced learning environment for students and enable them to retain more information and understand challenging subject matter.

Cost and Accessibility Challenges

The current economic constraints of advanced technologies still limit their adoption in mainstream educational practices. The simulation capabilities offered by VR systems, such as those offered by HTC Vive, are compelling, but their financial expenditure is certainly a concern for educational institutions operating under constrained budgets. In addition, other requirements, such as the need for high bandwidth internet and reliable power sources, make the use of these systems in many educational settings impractical. While the standalone VR systems offered by Oculus Quest are more economically priced and easier to access due to their lack of infrastructure dependence (Nissim & Weissblueth, 2017), their processing power restricts the number of sophisticated simulations that can be executed in areas such as medicine or engineering; whereas, the use of smartphones and tablets as AR devices renders AR technologies more accessible. These technologies are compatible with standard school equipment, enhancing their feasibility for institutions with limited technological resources. Regardless, the significant differences in the cost of VR, AR, and MR systems maintain a situation where schools that are financially advantaged still obtain the benefits. Izard *et al.* (2017) attempts to close this gap have begun. More affordable mixed-reality devices compatible with standard computers are being sold by Space. Besides, Google is offering wider access to virtual and augmented reality with its cost-effective Cardboard headsets. These efforts are allowing educational institutions of varying social and economic levels to adopt VR technology in the classroom.

Future Integration and Research

The realization of the potential of VR in education is contingent on alleviating economic barriers, driven by continuous research and technological progress. With the infrastructure of 5G networks in conjunction with cloud-based VR and AR systems, educational institutions could circumvent costly hardware purchases by making virtual learning content subscriptions accessible. This integration combined with AI could deliver individualized educational materials that cater to a diverse range of students. Longitudinal research studies analyzing the long-term effects of VR on education processes and skill development are crucial for thorough understanding. Such research can equip educators with evidence-based guidelines for designing effective VR teaching materials and contribute to the establishment of standards for immersive education in relevant educational settings worldwide. Responsible deployment of new technologies can optimize the use of VR, AR, and MR in enhancing educational experiences for all students.

Conclusion

VR exhibits a transformative capacity in education. Its design characteristics facilitate immersive, engaging, and interactive learning environments that significantly enhance student engagement, motivation, and learning effectiveness across a multitude of disciplines. Encouraging results have been observed in secondary and tertiary education, particularly in enhancing the understanding of complex and traditionally challenging subjects and promoting experiential learning opportunities. Therefore, this analysis has identified critical areas necessitating further studies. However, the effective implementation and scalability of VR are closely related to the rigorous consideration of ethical principles, cultural variations, and long-term consequences. For institutions seeking to leverage the benefits of VR while upholding ethical standards, compliance to ethical considerations such as data privacy, potential psychological ramifications, and the avoidance of over-reliance on technology holds critical significance. Effective implementation, guided by a responsible and ethical model, necessitates the development of specific data privacy frameworks, careful consideration of exposure duration, and validation that VR enhances, rather than substitutes, genuine learning experiences. Emerging trends, such as augmented reality, further enrich the explanatory and experiential dimensions of education, cultivating the creation of novel hybrid educational modalities. Future research should prioritize the development of affordable VR technologies for deployment in underserved communities, while pursuing ongoing analyses into the long-term impacts of VR on cognition, memory, and skill acquisition. Organizations such as EarlyLee have established the goal of enhancing the accessibility of these technologies for educationally disadvantaged populations. With optimized small-scale studies and the mitigation of global access disparities, VR has the potential to realize its objective of establishing a global foundation for inclusive and equitable learning across diverse cultures and socioeconomic backgrounds.

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