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The Impact of Virtual Reality on Student Engagement and Learning Outcomes in Technological Learning Environment – A SWOT Analysis

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Abstract*—Virtual reality (VR) is a transformative educational tool that addresses challenges in student engagement, inclusivity, and learning outcomes. By creating immersive and interactive learning environments, VR enhances motivation, critical thinking, and skill acquisition, particularly in STEM (Science, Technology, Engineering, and Mathematics), healthcare, and engineering disciplines. Its strengths include personalized and gamified experiences that enhance accessibility for students with diverse needs, including those from marginalized and disabled backgrounds. However, VR adoption faces significant barriers, such as technical issues, motion sickness, hardware malfunctions, high costs, and reliance on robust infrastructure, particularly in under-resourced environments. Educator reluctance, driven by a steep learning curve and pedagogical uncertainty, further hinders integration. This study aims to examine the strengths, weaknesses, opportunities, and threats (SWOT) associated with virtual reality (VR) in education, providing a detailed overview. SWOT, a descriptive framework developed in the 1960s for business planning, facilitates a precise analysis by classifying internal strengths and weaknesses alongside external opportunities and threats, making it the preferred tool for this study. Its practical use extends to fields such as engineering, medicine, biology, physics, chemistry, sports, music, and the arts, enabling insights into educational technologies. Despite challenges, VR offers opportunities such as scalability, interdisciplinary applications, and remote learning. Advances in affordable VR systems and hybrid virtual-augmented technologies hold promise for enhancing engagement and learning outcomes across diverse educational environments. A SWOT analysis highlights the potential of VR to address financial constraints and institutional opposition, while also improving inclusivity. Future studies should prioritize long-term evaluations and cost-efficient solutions, ensuring scalable and equitable adoption in education.

***Keywords*— Virtual Reality; student engagement; learning outcomes; SWOT analysis.**

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I. INTRODUCTION

Virtual reality (VR) has emerged as a groundbreaking educational technology that addresses conventional challenges in student engagement, inclusivity, and learning outcomes. In the field of education, disengagement and a deficiency in motivation frequently restrict cognitive and emotional learning processes, especially in demanding disciplines such as science, engineering, and healthcare [1]. The immersive and interactive features of VR provide a means to establish dynamic, experiential learning environments that foster increased engagement, critical thinking, and problem-solving abilities. For example, investigations have shown that VR-based learning significantly enhances motivation and understanding compared to conventional teaching approaches [2]. According to [3], the growing impact is seen in the swift growth of the global VR market in education, which is anticipated to rise $11.8 billion in 2023 to $61.55 billion in 2033, exhibiting an impressive compound annual growth rate (CAGR) of 39.1%, as shown in Fig. 1.

The incorporation of gamification and real-time interactivity in VR creates an engaging educational experience that meets various learning needs and enhances knowledge retention [4]. The potential of VR is significantly highlighted by its capacity to improve accessibility and inclusiveness in education at multiple levels. Personalized VR environments facilitate individualized educational experiences for students with varying abilities, encompassing individuals with disabilities or learning difficulties [5].

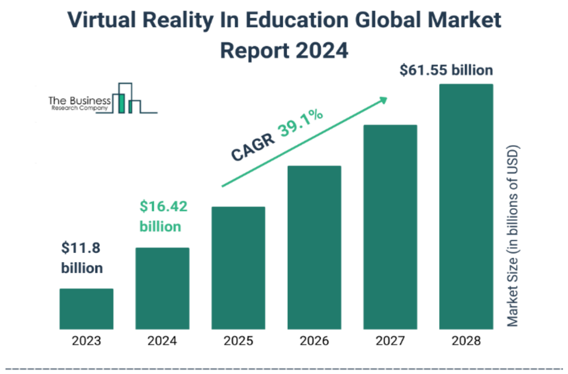

Fig. 1 Global Market Growth of VR in Education (2023-2033) [1]

Additionally, VR tools make it easier to picture complicated theoretical information in ways that traditional methods cannot. This makes it much easier to understand complex ideas in Science, Technology, Engineering, and Mathematics (STEM) fields [6], [7]. A study in industrial engineering found that VR-assisted modules improved digital competencies and technical understanding, particularly among undergraduate students [8]. Additionally, VR enables collaborative and interactive simulations, minimizing physical barriers in remote learning and providing equitable educational experiences to marginalized communities [9].

Nonetheless, despite these strengths, VR encounters considerable weaknesses and threats that hinder its broader acceptance. Technical challenges, including motion sickness, hardware malfunctions, and high equipment costs, remain significant obstacles [10]. The dependence on strong internet connectivity and sophisticated VR-compatible devices adds layers of complexity to implementation, particularly in educational environments that lack resources [11]. The reluctance of educators to embrace technology, arising from a challenging learning curve or doubts about its effectiveness in teaching, introduces an additional layer of complexity [12]. Moreover, recent studies have highlighted concerns regarding the overuse of VR, which may result in superficial learning or a diminished emphasis on higher-order cognitive skills (HOTS) [13].

This study aims to examine the strengths, weaknesses, opportunities, and threats (SWOT) associated with VR technology in education, providing a comprehensive overview. SWOT is a descriptive framework that facilitates the examination of possibilities and challenges by classifying factors into internal strengths and weaknesses, as well as external opportunities and threats [14], [15]. This method provides greater analytical precision compared to focusing solely on possibilities and challenges, making it the preferred choice in this study. While initially created in the 1960s to aid strategic business planning [16], its practical applicability has led to numerous studies utilizing SWOT to analyze educational technology contexts such as engineering [17], medical [18], biology [19], physics [20], chemistry [21], sports [22], music [23], and arts [24].

This study distinguishes itself by employing the SWOT analysis framework to provide a comprehensive assessment of VR in a technological learning environment, considering its strengths and opportunities alongside its limitations and challenges. This approach offers practical insights for overcoming obstacles and enhancing the scalability of VR to meet a range of educational needs. Fig. 2 provides a comprehensive overview of the SWOT analysis performed for VR within educational environments:

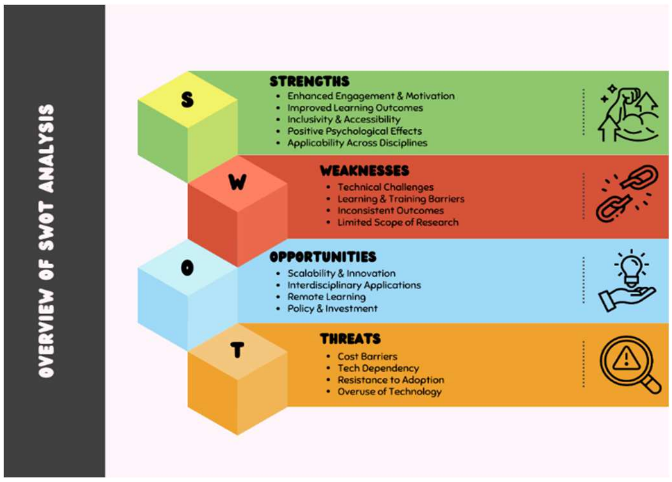

Fig. 2 Overview of SWOT analysis

The objective of this study is to identify the key benefits of VR in enhancing engagement, inclusivity, and learning outcomes while addressing the limitations and barriers to its adoption. Additionally, the study explores emerging opportunities for VR, including scalability, remote learning, and interdisciplinary applications, to highlight its broader impact. Ultimately, the study examines approaches to address current challenges, including financial constraints, reliance on technology, and opposition from institutions. This study provides practical insights to support policymakers, educators, and institutions in the practical and equitable implementation of VR, addressing the following research objectives.

II. Materials and Method

A. Strengths

A key strength of VR in education is its capacity to enhance student engagement and motivation across various educational levels. This is essential because disengagement and a lack of motivation are persistent issues in traditional learning environments, which limit students' cognitive and emotional engagement in the educational process. Studies consistently show that VR environments surpass traditional methods by leveraging aspects such as immersion, interactivity, and gamification, which collectively enhance cognitive, emotional, and social engagement.

For example, investigations indicate that students in immersive virtual reality (IVR) classrooms exhibit heightened behavioral and emotional engagement relative to those in traditional environments [25], as the implementation of head-mounted displays (HMDs) and interactive feedback promotes a deeper connection to the content and encourages engagement. Additionally, VR platforms, such as gamified social VR, have demonstrated their ability to promote critical thinking and self-directed interest through personalized and interactive learning experiences [26].

This is evident from the fact that students are taking more initiative and showing greater enthusiasm for postgraduate distance learning. In contrast to asynchronous or lecture-based approaches, VR demonstrates remarkable effectiveness in promoting active engagement, particularly among students with diverse learning needs [27]. Immersive environments have successfully initiated motivational challenges and offered improved assistance for students with disabilities.

Moreover, the extensive influence of VR encompasses its ability to scale and adapt to various fields and student groups, effectively tackling issues of accessibility and inclusivity. This is evident in its use for students with special needs [28], with 97% of participants indicating that VR was effective in elucidating complex concepts and enhancing practical skills. For instance, activities utilizing VR in industrial engineering courses not only improved digital competencies but also explained intricate concepts, showcasing the medium's adaptability and effectiveness across diverse educational environments. This shows that the ability of VR to enhance engagement and motivation marks a transformative strength, synchronizing with modern pedagogical goals to create dynamic, inclusive, and effective learning experiences.

The ability of VR to improve learning outcomes, particularly in STEM or technical disciplines, marks a significant strength. This is important as it addresses the difficulty of involving students in intricate subjects that demand advanced problem-solving, critical thinking, and creativity. Studies indicate a clear advantage; for example, investigations have shown that IVR environments improve academic performance and problem-solving abilities, particularly in engineering education, where VR has particularly exceeded traditional methods [29]. This highlights the potential of VR to explain complex technical concepts, thereby enhancing comprehension and engagement.

Integrating spherical video-based VR into elementary science inquiry activities significantly enhanced problem-solving skills, particularly benefiting students with initially poor learning attitudes [30]. This illustrates the capacity of VR to improve critical thinking and promote inclusivity by accommodating diverse learning styles and profiles.

Furthermore, VR facilitates the enhancement of skills and promotes creativity in practical contexts. A study using portable and cost-effective smartphone-based VR systems in classroom instruction showed improved cognitive learning and engagement, underscoring the feasibility and scalability of VR and its impact on learning outcomes [31], [32], [33].

Such findings highlight the accessibility of VR and its potential for broad adoption across various educational levels. This is because adding virtual and real research labs to technical education at the university level significantly improved students' understanding of complex topics such as electron microscopy [34]. Overall, VR effectively connects theoretical knowledge with practical application. These studies highlight the potential that VR has in modern education as it effectively addresses the demand for critical thinking, creativity, and improved learning outcomes.

Inclusivity and accessibility in education are advanced through the use of VR, as it supports students with a diverse range of capabilities, thereby effectively reducing barriers to their learning. It has enabled personalized experiences tailored to individual needs, which traditional methods often fail to achieve [35]. Besides, VR accommodates diverse learning styles through its personalized and gamified designs, enhancing engagement and comprehension for a broader spectrum of students [36]. These features represent a significant improvement over traditional approaches, which often lack the flexibility to adapt to the unique needs of individual students.

For instance, studies report that IVR environments significantly enhance cognitive presence and active participation, particularly among students with physical or mental challenges, demonstrating the effectiveness of this technology in addressing diverse educational requirements [37]. The broader impact of these advancements lies in their potential for scalability and inclusivity, providing proper access to quality education across various disciplines and levels. These results indicate the fundamental role of VR in encouraging personalized learning experiences, aligning with the larger educational goals of equity and accessibility.

The implementation of VR has been shown to yield significant positive psychological effects for students. These effects encompass heightened motivation, enhanced satisfaction, and a decrease in anxiety levels, especially within collaborative and simulation-based contexts. The significance of these effects lies in their potential to mitigate challenges such as disengagement and learning-related stress, which frequently obstruct academic performance. Studies indicate that IVR experiences significantly improve emotional and cognitive outcomes by promoting a greater sense of presence and enjoyment, thereby establishing a more engaging learning environment compared to traditional conventional educational frameworks [38].

In contrast to traditional approaches, VR fosters an enhanced experience of flow and immersion, which is correlated with increased satisfaction and prolonged motivation. This is supported by findings from high school students who expressed a 98.1% positive attitude towards VR-based learning environments. Additionally, the ability of VR to reduce anxiety is particularly beneficial in medical and simulation-based training environments, as evidenced by the fact that students reported feeling more prepared and less nervous after using VR compared to other resources [39].

The extensive implications of these psychological advantages include the promotion of sustained student engagement and the enhancement of overall educational outcomes across various fields of study. For example, a study emphasizes that university students engaged in engineering courses utilizing VR reported heightened focus and emotional comfort, which subsequently contributed to increased satisfaction and an enriched learning experience [40]. The results highlight the significance of VR in transforming the psychological aspects of education, positioning it as a powerful tool that creates a more engaging and less stressful learning environment.

VR is a significant strength in education due to its broad applicability across disciplines, effectively enhancing learning in fields such as science [41], engineering [42], healthcare [43], and the arts [44]. This versatility is essential, as it allows educators to design immersive and practical experiences tailored to the diverse academic needs of their students. For instance, [45] found that IVR-based situated learning improved nursing students' clinical skills and problem-solving abilities, while [47] depicted that VR facilitated greater engagement and comprehension in programming education when compared to traditional video methods.

In medical training, [48] emphasized the effectiveness of VR in enhancing kinesthetic learning outcomes, showcasing its superiority compared to traditional methods. Additionally, [49] noted that VR has the potential to improve autonomy and collaboration, thereby further increasing engagement levels.

The results demonstrate the distinctive ability of VR to merge theoretical understanding with practical implementation, establishing it as a crucial resource across various fields. The immersive and interactive characteristics of VR establish it as a more effective option for enhancing student engagement and improving learning outcomes. The following table (Table I) provides a summary of the key strengths of VR in education, consolidating its transformative impact on engagement, inclusivity, and learning outcomes across various disciplines.

TABLE I
KEY STRENGTHS OF VR IN EDUCATION

Strength	Description	Examples
Engagement	Boosts engagement via immersion, interactivity and games.	IVR classrooms with HMDs and gamified VR [25], [26].
Accessibility	Tailors learning for diverse needs, including disabilities.	97% found VR effective; aids special needs [28], [37].
Scalability	Works across various levels and disciplines.	Smartphone VR improves comprehension [33].
Learning Outcomes	Enhances problem solving, creativity, and critical thinking.	Better results in STEM and nursing [29], [45].
Inclusivity	Reduces learning barriers for all profiles.	Engages students with challenges [36], [37].
Psychological Benefits	Lowers anxiety and boosts motivation and satisfaction.	Positive attitudes; reduced stress [38], [39].
Interdisciplinary Use	Applicable across diverse fields such as science and arts.	Improves clinical and programming skills [43],[46],[47].

Thus, VR provides a powerful means to create a dynamic, inclusive, and practical learning experience by leveraging these strengths, aligning education with contemporary demands for innovation and accessibility.

B. Weaknesses

VR technologies often encounter technical issues, such as motion sickness, dizziness, and malfunctions, which can disrupt the learning process. These challenges hinder the seamless adoption of VR in classrooms, as discomfort and interruption can reduce engagement levels as well as learning outcomes. For instance, initiatives such as the "Tec Time Travelers" project highlight the need for cost-effective solutions to promote engagement through immersive learning modules [46]. Compared to traditional teaching methods, those that utilize technology do not face such technical constraints, making them more reliable in underfunded educational environments. Addressing these issues through funding and technological improvements is important for VR to become a sustainable educational tool.

The steep learning curve associated with VR presents a significant barrier for both students and educators. Educators with limited proficiency in virtual reality (VR) tools often struggle to integrate them effectively into their teaching, thereby reducing the potential benefits. Structured training frameworks and peer-led workshops have demonstrated efficacy in mitigating these barriers and improving implementation outcomes. Professional development programs have shown a positive correlation with enhanced educator engagement and competence, particularly when adequately resourced [51]. In contrast to conventional training methods, VR training requires a significant upfront investment in time and resources, which may lead to slow adoption. Enhancing the availability of training programs for educators and students has the potential to effectively address these limitations.

The impact of VR on learning outcomes varies widely, depending on factors such as prior knowledge, demographic differences, and engagement levels. In some cases, VR underperforms compared to traditional methods in terms of procedural knowledge acquisition, highlighting the need for more personalized approaches to content delivery. For example, a study on gamified VR systems demonstrates improved engagement, but inconsistent outcomes in knowledge retention [52]. Traditional methods often provide more uniform results across diverse populations. However, adaptive VR systems tailored to specific learning needs can help bridge this gap and offer equitable experience for all students.

Studies have shown that the long-term effectiveness of VR remains constrained by small sample sizes and short study durations, thereby limiting the generalizability of the findings. Current studies often focus on specific demographics or use convenience samples, making it difficult to apply results to broader populations. For instance, [53] emphasizes the need for more longitudinal studies to understand better the impact of VR on complex subjects such as mathematics. In contrast to the well-established body of research in traditional education, which has been developed over many decades, studies focused on VR remain in the early stages of exploration. Implementing extensive, multi-cohort studies may yield the necessary data to enhance VR-based educational tools and assess their long-term effectiveness.

In summary, the technical challenges, learning barriers, inconsistent outcomes, and limited scope of research hinder the full potential of VR in education. Addressing these weaknesses through targeted training, improved technology, and expanded study will enable VR to evolve into a more reliable and inclusive learning tool.

C. Opportunities

The application of VR in the educational environment offers numerous opportunities, including scalability and innovation, interdisciplinary applications, remote learning, and policy and investment benefits. The emergence of these opportunities can be attributed to technological advancement, enhanced accessibility, and the capacity to meet a variety of educational requirements. This highlights significant opportunities that VR presents for enhancing student engagement and learning outcomes within technological learning environments.

The growing affordability and accessibility of portable VR systems is a pivotal opportunity for scaling immersive educational systems. Affordable, smartphone-based platforms facilitate broader access to VR, allowing institutions with constrained resources to integrate advanced technology into their academic programs. The study conducted by [54] illustrated the effectiveness of a cost-efficient VR application in enhancing students' understanding and practical abilities within distance education environments, highlighting the capability of portable systems to address resource disparities.

In contrast to conventional approaches, these systems not only minimize infrastructural expenses but also provide a scalable framework capable of reaching marginalized students. The scalability observed in this context promotes enhanced equity within the educational environment, providing students from varied backgrounds with opportunities to participate in the immersive learning experience. Besides, the continued innovation in gamified, adaptive, and collaborative VR environments provides transformative possibilities for personalized learning. The integration of gamification and adaptive features within VR enhances motivation by customizing instruction to meet individual needs, thereby improving engagement and retention rates.

The framework for Multimodal Learning Analytics (MMLA) put forth by [55] serves as a prime illustration of this potential. When VR is combined with learning management systems, it facilitates the provision of adaptive feedback and personalized learning paths. This increases engagement and provides valuable insights into how people behave. In contrast to traditional static learning management systems (LMS), these advancements offer a dynamic and responsive learning experience, thereby enhancing engagement and effectiveness in education.

Furthermore, these developments present opportunities for vocational and skill-based training, allowing students to gain practical competencies within immersive, controlled environments. Moreover, VR opens up avenues for interdisciplinary applications by extending its reach to underexplored fields, such as the social sciences, humanities, and vocational education. The capacity of VR to replicate real-world scenarios enhances experiential learning, rendering it particularly advantageous for fields where the application of theoretical knowledge is essential.

This investigation, conducted by [56], revealed that IVR significantly enhanced skill transfer in design-related disciplines, exceeding the efficacy of conventional approaches. This demonstrates that integrating VR with emerging technologies, such as AR and artificial intelligence (AI), yields hybrid systems that enhance overall learning outcomes. In 2024, [57] demonstrated that incorporating AR into challenging subjects significantly improved students' abilities to learn and become engaged in the learning process. This suggests that hybrid VR/AR solutions could be highly beneficial, as the integration of various disciplines enhances the scope and significance of VR's impact across multiple fields.

VR addresses challenges in remote learning by creating immersive and interactive environments. The isolation often associated with remote education can be reduced through the capacity of VR to simulate physical classrooms and promote social interactions among students. A study conducted by [58] found that VR-based synchronous learning environments significantly enhanced student motivation and sociability when compared to conventional web-based platforms. Additionally, adaptive VR systems are capable of meeting the diverse needs of a varied student population, including non-native speakers and individuals with disabilities. A study by [59] highlighted the significance of inclusive VR environments that integrate visual and interactive tools to assist students encountering language or accessibility challenges.

The capabilities of VR positioning are a significant instrument for enhancing inclusivity and accessibility in education. Ultimately, the development of policy and investment in VR infrastructure and training signifies a pivotal opportunity for institutional transformation. To fully support the potential of VR, governments and educational institutions need to prioritize investments in teacher training, infrastructure development, and curriculum alignment.

The study investigated by [60], emphasized the significance of systematic VR integration, facilitated by trained educators and customized curricular strategies, in promoting creativity and critical thinking within STEM education. Additionally, collaborations among policymakers, educators, and VR developers can yield customized solutions that effectively address specific educational needs. The study [61] emphasized the effectiveness of collaborative efforts in rural China, highlighting that the integration of VR significantly improved instructional methods and increased student participation. Through the promotion of this collaboration, stakeholders can ensure that VR technologies are effectively integrated with educational objectives and infrastructure.

In conclusion, VR presents numerous opportunities for reshaping educational experiences across multiple levels. The scalability, interdisciplinary applications, inclusivity in remote learning, and potential for policy-driven growth establish VR as a fundamental element in the advancement of future educational innovation. When effectively utilized, these opportunities have the potential to transform student engagement and enhance learning outcomes within technological learning environments.

D. Threats

While VR technology has demonstrated significant potential for enhancing student engagement and learning outcomes, its integration into education presents substantial threats that could limit its adoption and effectiveness. Factors to consider encompass cost barriers, tech dependency, resistance to adoption and overuse of technology.

One of the primary threats to VR adoption in educational environments is the high cost of implementation, maintenance, and scaling. The financial implications of VR hardware, including HMDs, desktop VR systems, and software licensing, can be substantial, especially for institutions with limited funding. Furthermore, the necessity for ongoing maintenance and periodic upgrades to maintain compatibility with advancing VR technology contributes to the overall costs, presenting challenges to sustainability.

This results in unequal access, as institutions with constrained resources face challenges in implementing VR, thereby intensifying pre-existing educational disparities. For example, high-resource environments such as Purdue University have effectively implemented VR modules in engineering education, with reports indicating that 97% of students experienced heightened excitement and engagement [62]. However, the scalability of such initiatives in low-income schools remains a concern.

Similarly, a study on immersive STEM education has indicated enhanced usability and improved learning outcomes when utilizing IVR, compared to desktop VR and 2D platforms [63]. Nevertheless, the expenses associated with IVR systems remain considerably elevated, rendering them less practical for extensive implementation. In contrast to conventional methods, such as textbooks or video-based instruction, the immersive nature of VR offers distinct advantages in terms of engagement and retention [64]; however, the associated costs present challenges for widespread implementation. The implications of this financial obstacle may result in a digital divide, wherein only economically privileged institutions or areas gain access to VR-enhanced learning, thereby reinforcing existing educational disparities.

The heavy reliance of VR on reliable hardware and internet connectivity poses another major threat, particularly in low-resource settings. The lack of reliable access to high-speed internet and the limited availability of advanced VR-compatible devices in numerous educational settings present significant barriers to adoption, resulting in operational disruptions.

For example, a study examining VR-based streaming distance education indicated that users experienced discomfort associated with extended use of head-mounted displays, underscoring both technological and health-related issues [65]. Furthermore, the health risks linked to prolonged VR usage, including motion sickness, eye strain, and fatigue, may diminish its feasibility in educational settings. Despite VR's significant engagement advantages in fluid power education, some students found motion sickness to be a constraining factor [62].

Likewise, the use of VR for static activities in civil engineering has opened up positive engagement opportunities. However, the fact that interactive participation is limited suggests that it may be challenging to use VR in a healthy and balanced manner [66]. Unlike traditional methods such as video-based instruction or practical classroom activities, VR introduces technological complexities that may compromise accessibility. The extensive implications of technological dependency encompass obstacles faced by students in underdeveloped areas, where deficiencies in infrastructure hinder equitable access to advanced educational resources.

Cultural and institutional resistance to adopting VR remains a critical challenge, particularly among educators hesitant to shift from traditional teaching methods to technology-driven solutions. Educators and institutional leaders may exhibit uncertainty regarding the pedagogical efficacy of VR or encounter systemic obstacles when attempting to adapt current curricula to integrate immersive technologies.

For example, pre-service educators demonstrated heightened awareness and favorable perceptions of VR following practical workshops; however, this exposure remains constrained, underscoring the need for expanded teacher training programs [67]. Similarly, a study on technology acceptance has shown that performance expectancy and social influence serve as significant predictors of VR adoption within higher education. This highlights the necessity of mitigating skepticism by providing evidence-based demonstrations of the advantages associated with VR [68].

In contrast to conventional pedagogical approaches, VR necessitates substantial changes in instructional methodologies, potentially presenting challenges for educators who lack adequate training or institutional support. Resistance to adoption has significant implications, including the potential loss of opportunities to utilize VR as a means to improve student engagement and learning outcomes.

While VR introduces innovative possibilities, there is a risk of prioritizing technological novelty over pedagogical value. An excessive dependence on VR may result in inadequate learning experiences that fail to align effectively with established educational objectives. A study indicates that the immersive nature of VR may detract from its educational efficacy. This is evidenced in scientific simulations where generative strategies enhanced results, yet VR by itself did not demonstrate a significant advantage over conventional approaches [69]. Moreover, excessive engagement with VR could unintentionally diminish the focus on critical thinking and non-technical competencies.

For instance, collaborative VR activities within the context of engineering education exhibited constrained interactive engagement, notwithstanding the inherent collaborative capabilities of the technology [66]. This prompts an inquiry into the efficacy of VR environments in promoting higher-order cognitive skills in comparison to conventional learning environments or experiential learning approaches.

The extensive implications of excessive VR usage encompass the potential for superficial learning experiences, where students may prioritize immersive entertainment over substantive engagement. To address this issue, educators must ensure that VR applications are carefully aligned with educational objectives.

While VR technology offers significant opportunities to enhance student engagement and learning outcomes, its implementation in educational settings poses several challenges. The presence of substantial cost barriers, reliance on technology, reluctance to adopt, and potential risks associated with overuse highlight the necessity for a strategic and equitable approach to integrating VR within educational curricula.

To effectively address these challenges, it is essential to implement institutional investments, provide targeted teacher training, and adopt a balanced strategy that prioritizes the pedagogical value of VR over its technological allure. Failing to address these challenges may exacerbate educational inequalities and undermine the transformative potential of VR within academic environments.

III. Results and Discussion

The SWOT analysis presented in Table II emphasizes the significant transformative potential of VR within the educational field. VR enhances engagement, promotes inclusivity, and facilitates interdisciplinary learning opportunities while simultaneously addressing weaknesses in STEM education and improving accessibility for students with disabilities.

TABLE II
SWOT ANALYSIS OF VIRTUAL REALITY IN EDUCATION

Strengths	**Weaknesses**
Enhances student engagement and motivation via immersive experiences. ● Example: [25] discovered that, in contrast to traditional conditions, students became more excited and enthusiastic about the IVR lessons based on the IVR-based Classroom (IVRC) observations made during the learning activities.	Technical issues: motion sickness, hardware malfunctions, and dizziness. ● Example: Three major causes of VR sickness – hardware (e.g. display types), content (e.g. optical flow), and human factors (e.g., motion sickness history) – were identified [10].
Improve learning outcomes, especially in STEM and technical disciplines. ● Example: Students' performance improves significantly with VR systems, as this experiment provides qualitative proof of VR's superiority over non-VR and demonstrates that greater engagement with the environment enhances outcomes [29].	Steep learning curve for educators and students. ● Example: To address the initial challenges (e.g., setting up equipment and orientation), a more thoughtful approach was taken in the 1st class, allowing students to perform fewer tasks and complete fewer assignments [51].
Promotes inclusivity which tailored experiences for students with disabilities. ● Example: VR enables a truly flexible learning environment, allowing more students, including those who might not access a company's limited physical space, to benefit from open cases for academic or training purposes [28].	Inconsistent learning outcomes across diverse demographics. ● Example: No significant relationship was found between age and gender with a higher or lower total post-test average [52].
Reduces barriers to remote learning with interactive virtual environments. ● Example: Compared to traditional 2D lecture content, 360-degree VR lecture content is likely to be more engaging and advantageous for enhancing the capacity to organize and analyze raw information [5].	Limited research on long-term effectiveness and scalability. ● Example: There is limited evidence that VR significantly improves learning performance in training, but its advantage lies in fostering a strong sense of presence, enhancing skills learning [53].
Broad applicability across disciplines – (e.g., healthcare, engineering, arts). ● Example: Medical research supports the advantages of VR as it improved knowledge acquisition [4], increased learning by 60% in engineering education compared to traditional methods [40], and significant potential for positive impact in fields such as design and art [44].	High upfront costs for hardware and software implementation. ● Example: Maintaining physical science labs and ensuring safety can be expensive, while many advanced VR applications still require tethered HMDs connected to powerful computers, posing limitations for user studies [63].
Positive psychological effects such as reduced anxiety, increased satisfaction. ● Example: Almost every student rated the 360-degree VR video as inspiring (90.0%), enjoyable (86.7%), and helpful (100%) [39].	Dependence on strong infrastructure and reliable internet connectivity. ● Example: VR education programs are extremely useful because they bridge the communication gap between instructors and students, especially for those participating in remote learning programs [11].
Opportunities	**Threats**
Scalability: growing affordability of portable VR systems. ● Example: The lightweight design, affordability, and adaptability of motion-capture technology have broadened access to the virtual world, making it impressively realistic [11].	High costs hinder access for underfunded institutions. ● Example: If a developer can ensure that a VR user primarily focuses on a specific part of the scene, particularly the centre, this technique can help lower the computational costs associated in rendering the image [10].
Innovation in gamified, adaptive, and collaborative VR environments. ● Example: Gamification adds a new informational and operational layer to an existing activity or system, enabling administrators and managers to turn it into a game designed to encourage repeatable actions and reward desirable behaviors [26].	Technological dependency poses challenges in low-resource settings. ● Example: The most commonly reported barrier to using VR in classrooms was the lack of available software, equipment, training, and infrastructure (49.54%) [67].
Interdisciplinary applications in underexplored fields such as social sciences. ● Example: Backed by national policies, the transformation of resources into digital and virtual formats represents a key aspect of future education [56].	Resistance to adoption from educators and institutions. ● Example: Recent reviews and meta-analyses of IVR in education have identified several challenges within the field, such as the insufficient application of learning theories and a lack of theoretical and methodological rigor in research [69].
Enhanced remote learning and inclusivity for marginalized students. ● Example: Higher education institutions highlighted in this study should address the current situation by prioritizing engagement and interaction in online learning [59].	Overuse risks superficial learning over cognitive development. ● Example: The abundance of resources alone cannot guarantee effective intellectual engagement of students in their learning unless the cognitive process is directed using an appropriate andragogical approach [10].
Policy-driven growth and public-private collaborations. ● Example: The Organization for Economic Co-operation and Development (OECD) in its Future of Education and Skills 2030 document and the World Economic Forum (WEF) in its Towards a Reskilling Revolution report both highlight the importance of incorporating new cognitive tools to fully develop the soft skills of undergraduate students [60].	Health-risks: motion sickness, eye strain, and fatigue. ● Example: The significant challenges to the use of HMDs persist, including symptoms of cybersickness, insufficient software, and peripheral limitations [65].

Nevertheless, obstacles such as motion sickness, hardware malfunctions, and higher implementation costs hinder its broader adoption. The challenges associated with dependence on infrastructure and opposition from educators significantly hinder its potential for scalability. Despite these challenges, opportunities such as gamified environments, adaptive learning systems, and policy-driven investments present clear paths forward. It is crucial to address these weaknesses through targeted strategies, such as teacher training, cost subsidies, and infrastructure development, to ensure that VR can serve as a fundamental component of effective and equitable education systems.

IV. CONCLUSION

The analysis of immersive IVR in education highlights its transformative strengths, significant limitations, and considerable opportunities for growth. The capacity of VR to enhance engagement, motivation, and learning outcomes distinguishes it as a transformative educational tool, especially within fields such as STEM, healthcare, and engineering. This technology facilitates immersive, interactive, and personalized learning experiences, effectively addressing the challenges of disengagement and cognitive difficulties encountered in conventional teaching methodologies. Furthermore, the potential of VR to enhance accessibility and inclusivity for students with varying needs, including those with disabilities or from marginalized communities, highlights its significance as a fair educational approach [70]. Studies have consistently shown that utilizing experiential and game-based learning frameworks in VR can effectively bridge knowledge gaps, clarify complex theoretical concepts, and enhance critical thinking [13]. Policymakers have the opportunity to leverage these strengths by promoting targeted investments in VR technology within key sectors, particularly in STEM and healthcare, where significant skill gaps exist. Educators may consider integrating VR-based tools as supplementary aids to enhance the effectiveness of the curriculum.

Nonetheless, the integration of VR in educational environments continues to face ongoing technical and financial challenges. The feasibility of this technology is constrained by factors such as motion sickness, hardware malfunctions, and reliance on dependable infrastructure, particularly within institutions with insufficient funding. The elevated costs associated with equipment and the continuous need for maintenance significantly intensify educational inequalities, hindering the broad implementation in environments with limited resources [71]. The considerable learning curve faced by educators, along with the reluctance to embrace new technologies, represents a substantial obstacle to successful implementation. Further concerns about overuse underscore the risk that VR prioritizes immersive novelty over pedagogical value, potentially leading to superficial learning rather than higher-order cognitive development [72]. To mitigate these deficiencies, policymakers must prioritize resource allocation to close funding disparities in disadvantaged institutions, thereby ensuring equitable access. Educators need to collaborate with developers to jointly design VR experiences that are closely aligned with defined pedagogical objectives, thereby reducing the possibility of achieving only superficial learning outcomes.

Looking forward, future studies and advancements must focus on addressing these challenges to maximize VR's educational potential. Long-term studies are crucial for assessing the lasting effects of VR on learning outcomes, retention, and skill acquisition, especially in complex or specialized fields. Studies such as [73] provide valuable insights into designing scalable solutions that align with educational objectives and bridge existing research gaps.

Research needs to focus on the development of cost-efficient and scalable virtual reality (VR) systems that can be seamlessly integrated into educational environments with limited resources, while maintaining high standards of quality. Affordable VR platforms, as discussed in [74], have demonstrated significant promise, but further exploration is needed to balance cost with immersion and effectiveness. Additionally, the interdisciplinary integration of VR into emerging fields, such as healthcare and data sciences, holds great potential to extend its usability. For instance, [75], [76] highlight the importance of refining VR usability to support specialized applications, such as bioinformatics and data visualization.

Subsequent progress in VR technology, encompassing hybrid virtual-augmented reality solutions and multisensory feedback mechanisms, is poised to enhance the realism and fidelity of educational environments, thereby augmenting both cognitive and psychological engagement [73]. Besides, the implementation of structured training programs for educators is crucial to enable the effective incorporation of VR into current curricula, thereby ensuring its applications are aligned with educational goals and learning requirements.

Educators have the potential to capitalize on these opportunities by participating in trial initiatives that explore advanced VR innovations and assess their real-world effectiveness. Meanwhile, policymakers might consider promoting collaborations between the private and public sectors to expedite the creation of cost-effective VR solutions, particularly for underserved and marginalized areas. As highlighted by [77], fostering public-private partnerships can play a pivotal role in bridging the digital divide and ensuring equitable access to innovative educational technologies.

In conclusion, IVR technology holds immense promise for reshaping modern education by enhancing engagement, promoting inclusivity, and improving learning outcomes. By systematically addressing existing barriers, including financial constraints, technological limitations, and resistance to adoption, virtual reality (VR) has the potential to evolve into a scalable and sustainable educational tool. Future investigations and policy-oriented funding will be essential in addressing these challenges, facilitating the integration of VR into equitable, innovative, and effective educational frameworks globally. By strategically utilizing the insights derived from this SWOT analysis, policymakers can formulate evidence-based frameworks that enhance VR investments. Hence, educators can integrate this technology into customized teaching methodologies to achieve optimal outcomes in terms of both student engagement and learning outcomes.

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