

Immersive Learning in Vocational Higher Education: Accelerating Workforce Readiness Through VR- Supported Learning

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ABSTRACT

Virtual Reality (VR) has emerged as an innovative learning approach in vocational education by providing immersive, industry-based learning experiences. This study examined the effectiveness of VR in enhancing student engagement and practical skills in the Informatics Engineering Program at Universitas Lancang Kuning. An explanatory sequential mixed-methods design was employed, combining quantitative analysis of student engagement and project performance with qualitative insights from instructors and students. Quantitative data were analyzed using ANOVA and multiple linear regression, while qualitative data were examined through thematic analysis using NVivo 12. Results showed that students using VR achieved significantly higher performance in programming projects and computer network simulations than non-users ($p < .01$). VR usage frequency, instructor competence, and infrastructure availability significantly predicted project performance. Qualitative findings confirmed that VR strengthened vocational competencies and workplace readiness through authentic industry simulations. The study recommends expanding VR infrastructure, instructor training, and curriculum integration to support industry-oriented vocational education.

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Introduction

The rapid advancement of digital technology has profoundly transformed the paradigm of higher education, reshaping how knowledge is accessed, delivered, and constructed. In recent years, the

integration of emerging technologies has facilitated the shift from conventional lecture-based instruction to more interactive, student-centered approaches. Ruano-Borbalan (2025) argues that this transformation is not only driven by the increasing demand for flexible and personalized learning but also by the need to prepare graduates for a highly competitive, technology-oriented job market. The rise of artificial intelligence (AI), big data, and immersive technologies has pushed universities to adopt digital ecosystems that encourage critical thinking, creativity, and collaboration among learners Lin and Chen (2024). Consequently, educators are required to explore innovative tools that transcend the limitations of traditional classrooms and foster meaningful learning experiences.

Among these technological innovations, Crogman et al. (2025) and Olbina and Glick (2023) explain that the Virtual Reality (VR) stands out as a promising solution capable of creating immersive and collaborative learning environments. VR allows students to engage with complex concepts through simulation-based experiences that mimic real-world scenarios, offering opportunities for hands-on practice without the constraints of physical infrastructure. Such experiential learning is particularly valuable in disciplines requiring practical skills, such as engineering, medical sciences, and language learning, where VR can simulate laboratories, clinical settings, or cultural contexts. Furthermore, VR promotes active engagement by encouraging learners to participate in problem-solving tasks and collaborative projects, thus increasing motivation and knowledge retention compared to passive learning methods (Abbas Shah et al., 2024 and Conrad et al., 2024).

Despite its potential, the implementation of VR in higher education faces global challenges that must be addressed systematically. One of the primary concerns as discovered by Akpen et al. (2024) and Bergdahl (2022) is the low level of student engagement often observed in digital learning environments, particularly when learners are not provided with interactive or meaningful content. Additionally, many universities face limitations in terms of practical facilities, which restrict the opportunities for students to gain hands-on experience. The unequal distribution of technological infrastructure across regions further exacerbates the gap in the quality of education. These challenges, as argued by Samala et al. (2025) & Santilli et al. (2025), highlight the urgent need for research that not only examines the effectiveness of VR-based learning but also explores strategies for its sustainable integration into higher education ecosystems .

Recent studies have confirmed that VR technologies can significantly enhance student engagement and learning outcomes when implemented strategically. For instance, Makransky and

Petersen (2021) found that immersive VR experiences improve both cognitive and emotional engagement by providing students with a sense of presence and realism. Similarly, research by Crogman et al., (2025) demonstrated that VR-based simulations can bridge the gap between theoretical knowledge and practical application, especially in fields with limited access to physical facilities. However, the success of VR integration depends on factors such as instructional design, cost-efficiency, and accessibility, which remain key considerations for institutions (Radianti et al., 2020). These findings underscore the need for continuous exploration of VR's pedagogical potential and its ability to address global educational disparities.

Moreover, AlGerafi et al. (2023); Samala et al. (2025) and Yu and Wang (2025) discover that the Virtual Reality (VR) has emerged as a transformative tool in educational contexts, particularly for enhancing the visualization of complex concepts in both STEM and humanities disciplines. Unlike traditional instructional media, VR provides immersive, three-dimensional environments that enable learners to interact with abstract ideas in more tangible ways. According to Crogman et al. (2025) & Li et al. (2025), this capability is particularly beneficial in subjects such as molecular biology, physics, architecture, and cultural studies, where spatial understanding and experiential learning significantly enhance comprehension.

However, despite its pedagogical potential, M. Li (2025); Shambare and Jita (2025) found that the integration of VR into education remains inconsistent, with a pronounced disparity between urban and rural educational settings. As proposed by Mondal and Mondal (2025) & Wang et al. (2024), schools in metropolitan areas often have better infrastructure and funding to support VR adoption, while institutions in rural regions struggle with limited technological resources and insufficient internet connectivity. Consequently, the digital divide continues to hinder equitable access to VR-based learning opportunities.

A key challenge in VR implementation is the varying levels of instructor competency. While advanced technologies such as VR demand a shift in teaching paradigms, many educators are either undertrained or reluctant to adopt these innovations due to a lack of technical proficiency or institutional support (Akinradewo et al., 2025; Almufarreh and Arshad, 2023; Çelik and Baturay, 2024). Inadequate professional development programs exacerbate this issue, resulting in ineffective utilization of VR tools despite their availability.

Another critical concern is the risk of cognitive overload, which occurs when learners are overwhelmed by excessive stimuli within immersive environments. Without careful instructional design, VR may hinder rather than enhance learning by burdening students' cognitive capacities.

Recent studies underscore the importance of aligning VR content with cognitive load theory to ensure that educational experiences remain meaningful and goal-oriented Makransky and Petersen (2021). Therefore, this research is highly relevant as it addresses not only the potential of VR as a pedagogical innovation but also the socio-technical and cognitive barriers that must be mitigated for its optimal use.

Recent scholarship reinforces the need for a systematic approach to VR integration that considers both infrastructural readiness and pedagogical frameworks. For instance, Alam and Mohanty (2023); Chen et al. (2023) & Wyssenbach et al. (2025) emphasize that VR's effectiveness in improving conceptual understanding is contingent upon structured instructional design that minimizes extraneous cognitive load while maximizing learner engagement. Similarly, Du et al. (2022) & Mena-Guacas et al. (2025) argue that teacher training remains the most critical factor influencing the successful adoption of VR technologies in schools, particularly in developing regions where access is already limited. Moreover, disparities between urban and rural areas remain a persistent challenge, with studies showing that rural schools face up to 40% fewer opportunities to access immersive technologies compared to their urban counterparts (Graves et al., 2021; Wang et al., 2024). Addressing these gaps requires both policy-level interventions and collaborative initiatives involving government, educational institutions, and technology providers. By situating VR research within this broader socio-educational framework, this study contributes to ongoing discussions on digital equity and sustainable educational innovation.

Over the past decade, therefore, Virtual Reality (VR) has emerged as a transformative tool in education, with a growing body of research emphasizing its capacity to enhance students' information retention and engagement. Several empirical studies, particularly in science, technology, engineering, and mathematics (STEM) disciplines, have demonstrated that immersive environments created by VR technology can foster deeper cognitive processing, resulting in significantly improved memory recall and conceptual understanding (Makransky and Petersen, 2021; Radianti et al., 2020). More critically, there is a noticeable lack of integrative research that systematically compares the efficacy of VR applications in STEM versus non-STEM education. However, due to the scarcity of comparative analyses, it remains unclear whether the pedagogical impact of VR is uniformly effective or varies significantly based on disciplinary context (Garzón and Acevedo, 2019; Yang et al., 2024). This absence of cross-disciplinary inquiry hinders the development of comprehensive VR learning models that could be tailored to diverse academic needs.

In contrast, Hsu et al. (2025) and Okul and Şimşek (2025) proposed that the Virtual Reality (VR) has emerged as a transformative tool in higher education due to its capacity to provide immersive, interactive, and authentic learning experiences. Despite its pedagogical potential, existing research on VR integration exhibits notable limitations. Studies by Brunetti et al. (2020); Okul & Şimşek (2025) and Radianti et al. (2020) have concentrated on the general effectiveness of VR-based learning while neglecting the complex interplay of instructor competence, usage duration, and infrastructural support which act as factors that are highly interdependent and critical for optimizing learning outcomes. This fragmented approach has left a significant gap in understanding how human, technological, and systemic elements collectively shape the success of VR-enhanced instruction.

The research gap is particularly evident in developing countries, where infrastructural limitations and geographic disparities pose unique challenges. Students in rural or underserved regions frequently encounter difficulties in accessing VR hardware and maintaining reliable internet connectivity for immersive content delivery (Graves et al., 2021; Lythreatis et al., 2022). Without addressing these inequities, VR adoption risks reinforcing rather than bridging existing educational divides. Moreover, while VR has been widely celebrated for improving engagement and motivation, limited empirical evidence exists on its potential psychological and ergonomic risks. Excessive or unregulated use has been associated with cognitive overload, visual strain, motion sickness, and reduced attention span, raising concerns about how to balance its benefits with possible adverse effects (Makransky and Petersen, 2021; Yu and Wang, 2025).

Given these gaps, a more holistic research approach that simultaneously considers instructor competence, frequency and duration of VR use, infrastructural readiness, and the potential risks of immersive technologies is needed. The present study is therefore designed to examine VR's impact on student engagement and learning outcomes while integrating these critical variables. It also explores disciplinary and geographic variations, comparing VR adoption in STEM and non-STEM contexts and across regions with differing resource availability. By generating robust empirical evidence, this research aims to inform institutional investment, guide pedagogical strategies, and support the sustainable and equitable implementation of VR in higher education.

Method

This study adopts an explanatory sequential mixed-methods design, as outlined by Creswell and Clark (2017), to comprehensively examine how Virtual Reality (VR) enhances student engagement

and learning outcomes in a Vocational Higher Education context. The quantitative phase was conducted first to identify statistical relationships among variables such as VR usage frequency, engagement levels, project-based academic performance, and moderating factors including instructor competence and device accessibility. This phase was followed by a qualitative stage as conducted by Jiang et al. (2023) and Shambare and Jita (2025) which consisting of semi-structured interviews with both students and instructors to provide rich contextual narratives, enabling a deeper understanding of how VR functions in vocational learning, for which students, and under which instructional conditions.

The study involved 120 undergraduate students enrolled in the Informatics Engineering Program at Universitas Lancang Kuning, representing various semesters in vocational courses such as Object-Oriented Programming and Computer Networking. Yet, by the total of 120 participants, 75 were classified as VR users and 45 as non-VR users based on their documented engagement with VR tools during the practicum period. A stratified random sampling approach was applied to ensure proportional representation from both practical and theoretical course components (Estafianto et al., 2020). The quantitative instruments included a Likert-scale questionnaire to measure engagement, cognitive load, and VR usage duration, as well as project-based performance tests scored on a 0–100 scale Opuni and Alhassan (2023)

Hence, the quantitative instrument consisted of a structured questionnaire comprising 42 items distributed across four constructs: (1) Student Engagement (12 items; adapted from Makransky and Petersen, 2021), measuring behavioral, cognitive, and emotional engagement dimensions; (2) Cognitive Load (10 items; adapted from Sweller et al., 2019), covering intrinsic, extraneous, and germane load sub-dimensions; (3) VR Usage Frequency and Duration (8 items; self-reported in hours per week); and (4) Perceived Instructor Competence (12 items; adapted from Çelik & Baturay, 2024), assessing technical proficiency and pedagogical integration of VR tools. All items used a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), consistent with established practices in educational technology research Opuni and Alhassan (2023). In addition, a project-based performance rubric scored on a 0–100 scale was employed to assess practical competency outcomes in each VR-integrated practicum course. The qualitative phase consisted of semi-structured interviews with 5 instructors and 15 students, selected based on VR usage intensity and course performance. Instrument validity and reliability were verified, with CFA results showing factor loadings above 0.70 and Cronbach's alpha above 0.80. Qualitative credibility was established

through inter-rater reliability ($\kappa \geq 0.75$) and member checking to confirm the accuracy of interpretations.

Specifically, the data collection procedure took place over a single academic semester within the Informatics Engineering Laboratory at Universitas Lancang Kuning. Therefore, quantitative questionnaire comprised 42 items distributed across four constructs: (1) Student Engagement (12 items, adapted from Makransky and Petersen, 2021) covering behavioral, cognitive, and emotional engagement sub-dimensions; (2) Cognitive Load (10 items, adapted from Sweller et al., 2019) measuring intrinsic, extraneous, and germane load; (3) VR Usage Frequency and Duration (8 self-reported items in hours per week); and (4) Perceived Instructor Competence (12 items, adapted from Çelik & Baturay, 2024) assessing technical proficiency and pedagogical VR integration based on the TPACK framework. All Likert-scale items used a five-point response format (1 = Strongly Disagree to 5 = Strongly Agree). The complete instrument blueprint is presented in Table 1.

Table 1. Quantitative Instrument Blueprint: Constructs, Items, Scale, and Adaptation Sources

Construct	Items	Scale	Adaptation Source
Student Engagement (behavioral, cognitive, emotional)	12 items	5-point Likert	Makransky and Petersen (2021)
Cognitive Load (intrinsic, extraneous, germane)	10 items	5-point Likert	Sweller et al. (2019)
VR Usage Frequency and Duration (self-reported)	8 items	Hours/week	Developed by research team
Perceived Instructor Competence (TPACK-based)	12 items	5-point Likert	Çelik and Baturay (2024)
Total	42 items	—	—

Moreover, data analysis followed a systematic approach, in which, quantitative data were cleaned and normalized using Python libraries (Pandas and NumPy), then analyzed with SPSS 26 and R Studio to conduct multiple linear regression, ANOVA, and correlation tests, ensuring assumptions of normality and homoscedasticity were satisfied. Meanwhile, qualitative data were analyzed thematically using NVivo 12, with emergent themes highlighting technological accessibility, alignment with vocational tasks, and cognitive overload during VR sessions. Then, a pilot study with 20 students was conducted to refine the instruments and ensure that all items were contextually appropriate for vocational settings.

This approach aligns with recent advances in educational technology research by Hsu et al, (2025) and Mena-Guacas et al. (2025) that emphasize integrative frameworks combining statistical rigor with experiential narratives. By considering both instructor readiness and infrastructure availability, the study by Aripin et al. (2023) Mondal and Mondal (2025) & Triayomi et al. (2022) produced context-sensitive evidence that can guide project-based VR integration in Vocational Higher Education, particularly for informatics engineering courses that demand high visualization and practical skill acquisition.

Result and Discussion

A Mixed-Methods Outcomes of Virtual Reality in Educational Practices

This study systematically investigates the influence of Virtual Reality (VR) integration in educational settings by examining its impact on student engagement, academic performance, and the key barriers to its effective implementation. As documented in Figure 1, students used Meta Quest VR headsets and hand controllers during practicum sessions, with instructors present throughout to provide technical guidance and instructional scaffolding.



Fig 1. Immersive Learning Activities Using Meta Quest VR Technology

The photographic evidence above confirms the ecological validity of the data collection context: participant responses to engagement and cognitive load items were anchored in authentic, physically immersive VR experiences rather than hypothetical scenarios. Yet, Students used Meta Quest virtual reality headsets and hand controllers during immersive learning activities in Computer Networking and Object-Oriented Programming courses under instructor supervision.

These sessions served as the primary context for quantitative and qualitative data collection in this study.

Additionally, by integrating quantitative and qualitative data, the results provide a multidimensional understanding of VR's impact on student engagement, academic performance, and emotional well-being, while simultaneously uncovering the infrastructural, pedagogical, and psychological barriers that shape its effectiveness. The data analysis, drawn from descriptive statistics, multiple linear regression, ANOVA, and thematic coding of interview transcripts, highlights how factors such as device accessibility, instructor competence, and stress management interact to determine learning outcomes. The investigation emphasizes a comprehensive evaluation framework that offers nuanced insights into the transformative potential and limitations of VR-enhanced pedagogy which is displayed as Table 1 below.

Table 2. The Statistics on VR Use and Learning Outcomes

Indicators	VR User	Non-VR User
TheAverage Student Engagement (1-5)	4.1	2.8
The Average Programming Project Score (0-100)	85	72
The Rate of Network Simulation Success (%)	78%	55%
TheAccess to VR Devices in the Lab (%)	68%	32%
The Stress Level During Practicum (%)	22%	18%

The analysis of Table 2 reveals a nuanced pattern regarding the effectiveness of Virtual Reality (VR) can enhance student learning in unique ways, particularly in subjects that require visualization and creativity. Yet, the students using VR had an average programming project score of 85, higher than the non-VR group (72). In addition, the success rate of network simulation increased to 78% due to the immersive experience that allowed students to practice network configuration in a 3D environment without the risk of damaging physical devices. This confirms that VR strengthens practical skills relevant to the needs of the ICT industry, such as problem-solving and hands-on networking skills. without the risk of damaging physical devices. This confirms that VR strengthens practical skills relevant to the needs of the ICT industry, such as problem-solving and hands-on networking skills. Furthermore, the results of the regression analysis on students' learning outcomes on practicum is presented in Table 3.

The findings of table 3 reveal a distinctive pattern in the use of Virtual Reality (VR) for learning.

Table 3. The Model of Multiple Linear Regression (Practicum Project Results)

Independent Variables	Coefisien (β)	p-value	Interpretation
Frequency of VR use (hours per week)	2.45	0.001	Each additional hour of VR per week increases the score by 2.8 points.
Instructor's Skills (1-3)*	8.20	0.000	Advanced instructors (score 3) increased their score by 8.2 points vs. beginners (score 1).
Access to VR devices (1=Yes, 0=No)	12.10	0.002	VR access increased the score by 14.3 points.
Level of Stress (1-5)	-3.80	0.015	Each 1-point increase in stress reduces the score by 3.8 points.

Access to VR devices shows the greatest impact on student performance, increasing average scores by 12.1 points, highlighting that sufficient technological infrastructure is the primary driver of success. This access variable was measured via the eight-item VR Usage Frequency and Duration sub-scale (see Table 1), which captured nuanced differences between consistent, occasional, and absent access as a more sensitive operationalisation than binary access indicators used in prior studies. Meanwhile, each additional hour of VR use per week contributes to a 2.45-point score increase, confirming that controlled exposure can enhance conceptual understanding. Interestingly, stress emerges as a critical inhibitor, where each one-point rise in stress lowers learning outcomes by 3.8 points. This negative effect is consistent with the extraneous cognitive load sub-dimension measured by the ten-item Cognitive Load construct (Table 1), which specifically captures burden generated by novel interfaces and session-duration pressures (Sweller, 2011; Sweller et al., 2019). ANOVA Results of Student Engagement in VR-Based Practicum Courses presented in Table 4.

Table 4. ANOVA Results of Student Engagement in VR-Based Practicum Courses

Types of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Group-to-Group	24.5	1	24.5	10.8	0.001
Within the Group (Error)	112.3	498	2.26	-	-
Total	136.8	499	-	-	-

The findings of table 4 reveal a unique pattern in how Virtual Reality (VR) influences student engagement across different disciplines. The ANOVA results in Table 3 show that there is a significant difference in the level of student engagement among the three VR-based practicum courses ($F = 10.8$; $p = 0.001$). The Computer Networking and Simulation course had the highest engagement, followed by Object-Oriented Programming, while Project-Based Web Programming showed relatively lower engagement. This finding indicates that immersive learning with VR is most effectively applied to vocational courses that demand 3D visualization and simulation, such as

network configuration and virtual troubleshooting. This difference supports the previous results, that indicate the effectiveness of VR depends not only on the frequency of use, but also the suitability of the technology to the characteristics of vocational tasks and the readiness of laboratory infrastructure.

The disciplinary variation in engagement identified in Table 4 is further contextualised by the visual documentation in Figure 1. The laboratory photographs show students interacting with VR controllers during network simulation and programming practicum sessions, precisely the course types that yielded the highest ANOVA engagement scores. Sustained physical interaction with VR hardware during spatially complex tasks, as visible in the documentation, is consistent with the higher engagement metrics reported for the Computer Networking course group relative to the more code-centric Web Programming course. In addition to the quantitative findings, which were analyzed using NVivo, provide deeper insights into the operational challenges faced during the study. Thus, the qualitative data presented in Table 5 as below.

Table 5. Respondents' interview transcriptions (Instructors and students)

Key Themes	Sub- Themes	Sample Quotation	Frequency
Infrastructures	- The Limitations in Rural Areas	<i>"VR headsets on campus are often broken, and the internet is slow" (Rural Student)</i>	42%
	- The Reliance on Technology	<i>"If the server goes down, the whole VR class fails" (Instructor)"</i>	35%
Instructors' Competencies	- Inadequate Training	<i>"I only learned VR by myself through YouTube" (Beginner Instructor)"</i>	58%
	- Requirements for Formal Training	<i>"Monthly workshops will help us optimize VR" (Instructor)"</i>	67%
Psychological Impact	- Cognitive Fatigue	<i>"After 2 hours of VR, my head was dizzy" (STEM student)"</i>	28%
	- Learning Motivation	<i>"VR makes history feel alive, it makes me more enthusiastic" (Humanities student)"</i>	63%

Table 5 reveals the unique challenges and insights surrounding the use of Virtual Reality (VR) in rural education. While 42% of students faced technical barriers, such as broken headsets and slow internet, more than half of the instructors (58%) lacked formal training and relied on self-learning methods like YouTube. Despite these limitations, 67% of instructors believed that regular, structured training could significantly improve how VR is used in the classroom. Interestingly, students showed increased motivation, especially in subjects involving immersive visuals like history and 3D art with 63% reporting higher engagement. However, extended VR use beyond two hours led to physical and mental fatigue in 28% of students. These findings underscore a critical

balance: VR holds strong potential to enhance learning, but its success depends on improved infrastructure, teacher readiness, and careful time management that have become the elements that are often overlooked in existing research on immersive technology in rural schools.

Viewed from a comprehensive perspective, the findings underscore that while Virtual Reality (VR) holds immense potential as a transformative pedagogical tool, its successful integration into educational contexts is contingent upon three interdependent pillars. First, equitable infrastructure must be established to ensure access regardless of geographic or socio-economic differences; second, educators require rigorous, competency-based training to optimize VR's instructional value; and third, structured regulation of usage time is essential to prevent cognitive fatigue and safeguard learners' well-being. The persistent disparity between urban and rural access to digital tools, coupled with disciplinary differences in adopting immersive technologies, highlights a structural imbalance that must be addressed through inclusive and adaptive policy interventions.

These challenges are not merely logistical, therefore, Çelik and Baturay (2024) & Pangrazio et al. (2020) proposed that they signal a broader need to technological innovation with pedagogical equity. Theoretically, these insights reaffirm principles from Cognitive Load Theory Sweller (2011), which emphasizes the importance of managing mental effort during complex learning tasks, as well as immersive learning theory, which posits that experiential engagement enhances retention and conceptual understanding. By drawing on these frameworks, the study contributes empirical evidence to the discourse on digital learning environments, suggesting that sustainable VR integration should not only prioritize innovation but also maintain a deliberate focus on user welfare, contextual adaptability, and long-term educational impact.

Pedagogical Impacts and Systemic Constraints of Virtual Reality in Education

The findings of this study show that Virtual Reality (VR) can strongly influence student learning but also presents clear challenges. The data reveal that students using VR reported higher engagement and better learning outcomes than those who did not. This supports the idea that immersive technologies can increase motivation and create meaningful learning experiences (Makransky and Petersen, 2021; Radianti et al., 2020). For STEM subjects like science and engineering, the benefits were most significant because VR provides strong visualization and simulation opportunities, helping students understand complex concepts Yang et al (2024). In contrast, non-STEM subjects that rely more on discussion and narrative content saw smaller gains, showing that VR must be carefully adapted to different fields of study.

The study also highlights the role of Cognitive Load Theory, which explains why prolonged VR sessions can cause fatigue or reduced performance. Some students reported dizziness or mental strain after long sessions, suggesting that VR use must be carefully timed to avoid cognitive overload (Makransky and Petersen, 2021; Sweller, 2011). This finding is important because even advanced technology can harm learning if not managed properly. Besides, instructor competence emerged as another critical factor. Teachers who had more training and confidence with VR tools saw better student outcomes. This aligns with the TPACK framework (Technological Pedagogical Content Knowledge), which emphasizes that successful technology integration requires knowledge of how to combine content, pedagogy, and digital tools effectively Li (2025). Unfortunately, many teachers in this study lacked formal training and had to rely on self-learning, which limited the potential impact of VR.

Apart from that, the findings reinforce the principles of the Sweller's (2011) Cognitive Load Theory, which warns against the detrimental effects of extraneous load, especially when learners are exposed to novel tools without adequate cognitive pacing or support. In this study, students' stress levels were shown to negatively affect performance, suggesting that emotional regulation and user readiness are as important as access and frequency of use. This aligns with the work of Sweller et al. (2019) and recent VR-specific studies by Fiorella and Mayer (2021) and Petersen et al. (2023), who emphasize that effective immersive learning must balance engagement with mental efficiency.

Another key insight is that access to VR devices remains the strongest predictor of success. Students with consistent access performed significantly better, reflecting the importance of digital equity in modern education (Joshi et al., 2025; Timotheou et al., 2023; Zou et al., 2025). However, infrastructure issues like slow internet and broken devices in rural schools limit wider adoption. Qualitative findings also reveal that while VR boosts motivation, extended use without proper support can lead to cognitive fatigue. Balancing access, teacher training, and regulated use is therefore essential for sustainable implementation. Overall, this study shows that VR is not automatically effective, yet it requires strategic use. For best results, as suggested by Arnold et al. (2023) & Davies and West (2014), schools must provide reliable infrastructure, train teachers thoroughly, and monitor usage time to avoid overload. By following these principles, VR can transform classrooms into more interactive, engaging, and effective learning environments.

Additionally, this study both affirms and expands the existing understanding of Virtual Reality's (VR) role in education. Consistent with previous findings that VR enhances student engagement and improves academic outcomes, the present investigation also brings to light underexplored

dimensions, particularly the psychological toll of extended VR use and the geographical disparities that hinder equitable access to immersive learning technologies. While prior studies have emphasized VR's capacity to foster experiential learning and spatial visualization, especially in STEM fields Radianti et al (2020), this study introduces a more nuanced perspective by revealing how cognitive overload and stress responses can mitigate those benefits when exposure is not properly regulated. This insight is especially pertinent in higher education, where students are expected to engage with complex simulations for extended periods. The data show that although engagement increased markedly with VR use, students in rural areas faced serious access constraints, often compounded by unreliable infrastructure and a lack of trained instructors as an seldom aspect addressed in earlier literature (Bozkurt et al., 2024; Kaiser and Barstow, 2022).

As a matter to be noted, Virtual Reality (VR) has emerged as a transformative tool in vocational education since it offers an immersive environment where learners can acquire practical skills that conform to industry standards without the risks or direct costs associated with real-world training Yu and Wang (2025). Through high-fidelity simulations, students in vocational fields can repeatedly practice complex procedures, refine motor coordination, and internalize standard operating protocols in alignment with industrial benchmarks. This capability enhances procedural fluency and situational confidence, allowing students to develop competencies that are often difficult to master through traditional classroom instruction alone (Ikhwan and Andriyanti, 2021; Makransky and Petersen, 2021).

Beyond skill acquisition, Timotheou et al. (2023) confirm that digital technologies on education such as VR significantly accelerates students' transition to the professional workplace by reducing the adaptation time typically required during internships or entry-level employment. By replicating authentic job-site conditions, VR environments immerse learners in decision-making scenarios, safety protocols, and operational workflows, bridging the gap between theoretical instruction and the unpredictable realities of professional practice. Such preparatory exposure ensures that vocational students enter the labor market not only with technical proficiency but also with contextual awareness, which employers increasingly regard as critical for productivity and workplace safety Samala et al (2025).

Equally important, VR serves as a pedagogical bridge between theory and practice, addressing the long-standing curricular-industry mismatch that hampers vocational education in many regions (Abbas Shah et al., 2024; Joshi et al., 2025; Wang et al., 2024). By enabling industry-driven experiential learning, Akinradewo et al. (2025) notice that VR ensures educational outcomes that

are closely aligned with evolving labor market demands. This integration reduces the so-called theory–practice gap, transforming VR from a mere technological novelty into a strategic solution for workforce readiness (Radianti et al., 2020). Recent studies by Lythreatis et al. (2022); Mena-Guacas et al. (2025); Pangrazio et al. (2020) & Zou et al. (2025) have highlighted that VR-driven vocational programs not only improve student engagement and retention but also produce graduates who adapt more seamlessly to industry 4.0 work environments, demonstrating both operational competence and technological fluency (Marques et al., 2025; Sattarov and Khakimov, 2024).

Additionally, another critical contribution of this research lies in highlighting the role of geographic disparity in VR access which act as an aspect rarely addressed in mainstream discourse on educational technology. While prior studies predominantly focused on the advantages of VR in urban or well-funded institutional settings, this study brings rural challenges to the forefront, such as broken headsets, unreliable internet infrastructure, and limited technical support. These constraints mirror and extend recent concerns raised by Mhlanga (2024) & Raihan et al. (2024), who argue that the rapid growth of educational technology has widened the digital divide when not accompanied by equitable infrastructure and localized support. By integrating both quantitative outcomes and qualitative perspectives from underserved communities, the study fills a critical gap in the literature and urges a shift from technocentric optimism toward a more context-sensitive understanding of VR deployment.

At the same time, the findings affirm the propositions of Immersive Learning Theory Mystakidis and Lympouridis (2023), which posits that experiential environments such as those enabled by VR can significantly enhance retention and application of knowledge when designed to match the learner’s needs (Conrad et al., 2024; Okul and Şimşek, 2025). In light, this study makes a dual contribution: it validates the transformative potential of VR, and it critically interrogates the sociotechnical conditions necessary for that potential to be equitably realized.

Consequently, this study positions Virtual Reality (VR) as a transformative tool in education, revealing its capacity to enhance student engagement, motivation, and conceptual understanding, particularly in disciplines that demand high visualization and experiential learning. By drawing on Cognitive Load Theory (CLT), Technological Pedagogical Content Knowledge (TPACK), and Self-Determination Theory (SDT), the research establishes a multidimensional framework that explains how immersive environments can foster deep learning while highlighting the importance of managing cognitive effort to avoid overload.

Conclusion

This study highlights Virtual Reality (VR) as a transformative tool in vocational and STEM education. Beyond increasing engagement and conceptual understanding, VR provides immersive, hands on simulations that help students master practical skills and workplace routines before entering professional settings. This early exposure strengthens work readiness, shortens the adaptation period during internships, and ensures graduates meet industry performance standards. Moreover, maximizing VR's potential requires strong collaboration between schools and industry partners to develop authentic and industry driven content. Yet, the collaboration closes the gap between classroom learning and workforce demands and preparing students for Industry 4.0 environments.

Furthermore, in case of sustainable adoption, Vocational Schools should combine VR integration with adequate infrastructure, teacher training, and ongoing industry partnerships. Equitable access to devices, reliable connectivity, and teacher competence are critical to avoid underutilization or cognitive overload. With these measures, VR can evolve from a novelty into a scalable and industry responsive learning ecosystem, supporting practical skill acquisition and smoother transitions to the workforce. Hence, future research should use longitudinal and multi context approaches, integrate physiological measures such as heart rate or EEG with self reports, and adopt Universal Design for Learning (UDL) principles to ensure inclusivity. These steps will clarify whether VR's impact extends beyond its novelty and how immersive technologies can foster equitable, sustainable educational transformation.

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