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Improving Virtual Reality Assessment and Accessibility in the Technology Classroom

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Comparing Virtual Reality to Lecture in the STEM Classroom

1. Introduction

Virtual Reality (VR) has the potential to offer immersive, practical simulations that mirror real-world workplace scenarios, yet its limited accessibility poses significant barriers in higher education. High costs, technical infrastructure requirements, and the need for specialized equipment make VR less feasible for widespread use in education and workforce settings. As a result, the disparity in access to VR hinders its widespread adoption, especially for students from under-resourced institutions.

Due to this disparity in access to VR, the question remains – how effective is VR in comparison to traditional lecture?

To address this gap, the teaching team implemented a module using 20 borrowed Quest 1 VR headsets. During the module, students explored and reflected upon the challenges of VR adoption in education. After students completed an initial onboarding, each week focused on a different learning topic. In Week 1, students explored the Iceberg Model, followed by Creativity and Innovation in Immersive Technology in Week 2. In Week 3, the module concluded with Gamification for Increased Quality and Productivity. After the three weeks of topics (explored via VR and lecture), the final week was a project week. Students received traditional PowerPoint lectures and immersive VR experiences for each topic, enabling them to reflect on and compare the different learning modalities.

The guiding research question is as follows: *How do undergraduate STEM students perceive immersive Virtual Reality (VR) in terms of immersion, agency, presence, and motivation compared to traditional classroom settings?*

2. Background

2.1 Virtual Reality – History and Definitions

Virtual Reality (VR) is a technology that immerses users in a computer-generated, three-dimensional environment, enabling interaction through sensory stimuli such as sight and sound. This immersive experience is typically achieved using head-mounted displays (HMDs) equipped with motion tracking, allowing users to look and move around the virtual space as if they were physically present. The primary goal of VR is to create a sense of presence, making the user feel as though they are inside the virtual environment.

Virtual Reality has undergone a remarkable transformation from conceptual foundations to a dynamic tool across various industries. The journey began in the 1960s when Ivan Sutherland developed the first head-mounted display, introducing the idea of a computer-generated immersive experience that laid the groundwork for VR technology [1]. Throughout the 1980s and 1990s, VR gained traction in fields such as aviation and medicine, where it enhanced training and simulation capabilities, demonstrating VR's potential for experiential learning and skill-building [2]. However, technology remained largely limited to specialized sectors due to high costs and technological limitations.

The early 2000s saw advances in computing power and graphics that made VR more accessible and immersive, leading to increased research and experimentation in diverse fields. These developments paved the way for VR's entry into mainstream applications, including entertainment and education, where it has increasingly been adopted to provide interactive learning environments [3]. In recent years, further improvements in hardware and software have enhanced the user experience, enabling widespread use in both consumer and educational contexts [4].

Today, VR continues to evolve, with educators exploring its potential to create immersive and engaging environments that support various learning styles. By bridging the gap between theoretical knowledge and practical experience, VR is positioned as a transformative tool with applications that extend beyond entertainment into critical fields like healthcare, engineering, and education [5]. This history highlights VR's evolution from a niche technology to an influential tool in modern society.

The applications of VR are vast, spanning entertainment, education, healthcare, and more. In education, VR offers immersive learning experiences, enabling students to explore historical sites or conduct virtual science experiments. In healthcare, VR is used for surgical simulations and therapeutic interventions. The versatility of VR continues to expand as technology advances, offering new possibilities for immersive experiences across various fields.

2.2 Teaching and Learning with Virtual Reality – Benefits and Challenges

Integrating VR into educational settings offers numerous advantages that enhance both teaching and learning experiences. VR provides immersive experiences that captivate students' attention, making learning more engaging and enjoyable. By simulating real-world scenarios, VR fosters active participation, which can lead to increased motivation and a deeper interest in the subject matter [6]. VR enables students to explore environments and situations that are otherwise inaccessible, such as historical events, scientific phenomena, or distant geographical locations. This experiential learning approach allows students to gain a practical understanding of complex concepts, enhancing comprehension and retention. In fields like medicine, engineering, and aviation, VR offers a risk-free platform for students to practice skills and procedures. This controlled environment allows learners to make mistakes and learn from them without real-world consequences, thereby building confidence and competence [6].

VR can be tailored to individual learning needs, accommodating different learning styles and paces. This personalization ensures that each student can engage with the material in a way that suits them best, promoting more effective learning outcomes [7]. VR facilitates collaborative learning by allowing students to interact with peers and instructors in a shared virtual space. This interaction can enhance communication skills and teamwork, essential components of the learning process [8]. Incorporating VR into education not only enriches the learning experience but also prepares students for a technologically advanced world. As VR technology continues to evolve, its potential to transform education becomes increasingly evident.

Despite its numerous benefits, integrating VR into education presents a series of challenges that educators and institutions must address for effective implementation. One primary challenge is the high cost associated with VR technology. The expense of VR headsets, software, and maintenance can be prohibitive for many schools, particularly those with limited budgets. Additionally, technical requirements such as high-performance computers and updated software demand consistent funding and resources, making it difficult for some institutions to adopt VR on a large scale.

Health concerns are also notable, as extended VR use has been associated with motion sickness, eye strain, and fatigue. These issues can limit the duration for which students can safely use VR, posing a restriction on its potential as a primary instructional tool. The immersive nature of VR may also contribute to increased cognitive load, as students must manage the complexity of the virtual environment while focusing on the educational content, which can impact attention and learning outcomes.

Finally, there is a learning curve associated with VR for both educators and students. Teachers need training to use VR effectively, as many are not familiar with the technology's capabilities and limitations. This additional training requires time and resources, which may not always be feasible. Moreover, students may face initial difficulties in adapting to VR interfaces, impacting their ability to engage effectively in VR-based lessons. Addressing these challenges is essential to maximize VR's educational benefits and integrate it successfully into modern learning environments.

3. Methods

3.1 Participants

The participants included 40 students enrolled in a senior-level technology class titled, Leadership Strategies for Quality and Productivity, at a large research-intensive university in the Midwest. The participant pool was diverse in terms of age and academic standing. Ages ranged from 19 to 25. Participants were randomly assigned to either Group A or Group B, each consisting of 20 students. This study has IRB approval as Exempt Category 1.

3.2 Intervention

This study focused on comparing immersive Virtual Reality (VR) lessons with traditional PowerPoint (PPT) lessons, offering students a unique learning experience across three key topics. Each lesson included both an informative section and a hands-on experiential activity designed to be as consistent as possible between the two modalities. This approach enabled a direct comparison of student engagement, presence, and learning outcomes in each mode. The primary difference between the two formats was the level of immersion: VR utilized 3D environments and interactive elements, while PPT relied on conventional text, images, and in-person group activities. Table 1 provides an overview of the module intervention.

Table 1. VR Module Overview

Activity	Topic	Descriptors
Onboarding	1) Introduction to Immersive Technology and Metaverse & (2) Equipment/HMD Walkthrough	(1) Guest lectures on immersive technology, its applications in education and industry, and the Metaverse's implications for immersive learning & (2) Hands-on walkthrough of VR equipment and HMDs to familiarize students with immersive technology tools.
Week 1: Individual Lesson Comparisons	Leadership vs. Management	Students categorized leadership and management terms using both physical whiteboards (PPT) and virtual rooms (VR).
Week 2: Individual Lesson Comparisons	The Iceberg Model – Understanding Root Causes	Students analyzed root causes using the Iceberg Model and built space themed spaghetti towers. For PPT students built with noodles and marshmallows and in VR with 3D objects and drawing's
Week 3: Individual Lesson Comparisons	Gamification for Increased Quality and Productivity	Students explored gamification concepts through online games in PPT and interacted with virtual game mechanics in VR.

During Weeks 1-3, a cross-over design was used to balance for order effects such as fatigue or learning progression, the students were divided into two groups:

- Group A started with VR lessons on Tuesdays and switched to PPT on Thursdays.
- Group B started with PPT on Tuesdays and switched to VR on Thursdays.

This AB/BA counterbalancing minimized order effects while maintaining the integrity of the within-subject comparison. The analysis focused on individual-level data rather than group comparisons, isolating the impact of the instructional modality itself. Attendance was recorded for each lesson to ensure that only participating students were included in the analysis, particularly since student absenteeism could have been a factor (but was determined to not influence the study).

3.3 Data Collection

At the end of Weeks 1, 2, and 3, participants completed a reflective survey which included a 31-item questionnaire split into four subscales. Each subscale was derived from an instrument relating to one of the four key items from the CAMIL model [9]: Immersion, Presence, Agency, and Motivation. Each question was on a 6-point Likert scale, ranging from 1 (strongly disagree) to 6 (strongly agree). The specific stems and items can be seen in Tables 1-4 (within the Results section).

Each subscale was derived from validated scales. The Presence and Immersion Subscales were derived from the Presence Questionnaire [10]. These scales assessed students' sense of spatial presence and the depth of their immersive experience. Additionally, the study used the Sense of

Agency Rating Scale (SOARS) [11] to evaluate agency and the Intrinsic Motivation Inventory (IMI) to assess motivation, a scale grounded in Self-Determination Theory (SDT) [12, 13].

Internal consistency was also measured using Cronbach's Alpha. The combined scale, which includes all 31 items, had a value of 0.926. This indicates adequate reliability [14], suggesting that the scale items work well together to measure the constructs of motivation, presence, agency, and immersion.

3.4 Data Analysis

SPSS (Statistical Package for the Social Sciences) was used to analyze the data. SPSS is a powerful statistical software used for data analysis, management, and visualization. Developed by IBM, it is widely utilized in research, business, healthcare, and academia for tasks such as descriptive statistics, regression analysis, hypothesis testing, and predictive modeling. SPSS features an intuitive user interface, allowing users to analyze data without extensive programming knowledge, while also supporting advanced statistical techniques through syntax commands. SPSS is particularly valued for its ease of use, making complex statistical analysis accessible to a broad range of users. Descriptive statistics are provided in addition to a applying the Student's T-test to assess for a difference in means.

4. Results

4.1 Motivation: Comparative Analysis of VR and Traditional Learning Environments

Table 1 shows the results of the motivation survey items survey. The analysis of the motivation data reveals that while one item had a p-value below 0.05, indicating a statistically significant difference, the rest did not show significant differences between the VR and traditional groups. This suggests that the VR environment had a notable impact on student interest, but other motivation factors were comparable across both learning methods.

Table 1. Results for Comparative Analysis of VR and Traditional Learning Environments

1. Motivation based questions: Please identify to what extent you agree with these statements		
Statement	Mean Difference	Two-sided P-value
4.1.1- I feel this learning experience was enjoyable	-0.016	0.928
4.1.2 - I felt this learning experience was boring	0.012	0.953
4.1.3 - I felt this learning experience did not hold my attention	0.293	0.153
4.1.4 - I would describe this learning experience as interesting.	0.401	0.019*
4.1.5 - I felt this learning experience was enjoyable.	0.251	0.122
4.1.6 - I felt a sense of enjoyment during this learning experience.	0.180	0.296
4.1.7 - I felt this learning experience was fun.	0.252	0.125

*p-value significance: **<0.01; *<0.05*

4.2 Immersion: Comparative Analysis of VR and Traditional Learning Environments

The perceived results of the survey were measured post VR and Traditional learning experience. Table 2 shows the results of this survey. The analysis of the immersion data shows that most items had p-values below 0.05, indicating statistically significant differences between the VR and traditional groups. These results suggest that the VR learning environment had a notable impact on students' immersion levels compared to traditional methods.

Table 2. Results for Comparative Analysis of VR and Traditional Learning Environments

2. Immersion based questions: Please identify to what extent you agree with these statements		
Statement	Mean Difference	Two-sided P Value
4.2.1 - I feel I could easily move or manipulate objects during the learning experience	-0.651	0.003**
4.2.2 - I felt the technology effectively created a visually believable learning experience	-0.024	0.906
4.2.3 - I felt disoriented at the end of the learning experience.	1.222	<.001**
4.2.4 - I felt the visual display quality during the learning experience distracted me from performing assigned activities	1.056	<.001**
4.2.5 - I felt I could concentrate on the assigned activities rather than on the mechanisms used to perform them.	-0.709	<.001**
4.2.6 - I felt the technology used during the learning experience interfered with the ease of engaging in the activity.	0.669	0.003**
4.2.7 - I felt there was a delay between my movement and the expected outcomes in the learning experience.	1.274	<.001**

*p-value significance: **<0.01; *<0.05*

4.3 Presence: Comparative Analysis of VR and Traditional Learning Environments

Table 3 shows the results of the Presence survey items. The analysis of the Presence data reveals that all but two items had p-values below 0.05, indicating statistically significant differences between the VR and traditional groups. This suggests that students in the VR environment experienced a significantly higher sense of presence compared to those in the traditional learning environment.

Table 3. Results for Comparative Analysis of VR and Traditional Learning Environments

3. Presence based questions: Please identify to what extent you agree with these statements		
Statement	Mean Difference	Two-sided P Value
4.3.1 - I felt convinced the environment around me was realistic during the learning experience	-0.918	<.001**
4.3.2 - I felt it was easy to avoid distractions during the learning experience	-0.725	.001 **

4.3.3 - I felt the information from my senses was consistent.	-0.596	<.001**
4.3.4 - I felt myself in the moment during the learning experience to be reasonable and manageable	0.092	0.637
4.3.5 - I felt the overall mental effort required to complete this learning experience to be reasonable and manageable.	-0.486	<0.001 **
4.3.6 - I felt the learning experience should have been longer.	0.363	0.105
4.3.7 - I felt I lost track of time while in the learning experience.	0.696	0.003 **

*p-value significance: **<0.01; *<0.05*

4.4 Agency: Comparative Analysis of VR and Traditional Learning Environments

Table 4 shows the results of the Agency survey items. The analysis of the Agency data reveals that several items had p-values below 0.05, indicating statistically significant differences between the VR and traditional groups. These results suggest that students in the VR environment felt more control and agency over their learning experience, particularly in terms of their ability to follow instructions and perceive their actions as self-driven.

Table 4. Results for Comparative Analysis of VR and Traditional Learning Environments

4. Agency based questions: Please identify to what extent you agree with these statements		
Statement	Mean Difference	Two-sided P-Value
4.4.1 - I felt my experiences and actions were under my control.	-0.585	<0.001**
4.4.2 - I felt I had the ability to choose how to respond during the learning experience.	-0.422	0.006**
4.4.3 - I felt it was hard to follow the instructions.	0.649	<.001**
4.4.4 - I felt my experiences and actions were not caused by me.	0.492	0.016*
4.4.5 - I felt I was absorbed in what was going on.	-0.049	0.770
4.4.6 - I felt my experiences and actions originated from within me.	-0.272	0.107
4.4.7 - I felt my responses were involuntary.	0.139	0.506
4.4.8 - I felt I chose to follow the instructions freely without hesitation.	-0.289	0.054*
4.4.9 - I felt my experiences and actions occurred effortlessly.	-0.699	<0.001**
4.4.10 - I felt reluctant to follow the instructions.	0.380	0.051*

*p-value significance: **<0.01; *<0.05*

5. Discussion and Conclusion

This research investigated the comparative effectiveness of Virtual Reality (VR) learning environments versus traditional classroom settings in terms of student motivation, immersion, presence, and agency. Using a survey-based approach, data were collected from students who participated in both VR and traditional learning experiences. The results reveal that while VR significantly enhances student interest and provides a heightened sense of presence, it also introduces challenges, such as distractions from the visual display and increased cognitive load. In contrast, traditional learning methods were found to offer more consistent sensory feedback and better ease of concentration, particularly when manipulating objects or following instructions. Statistical analysis shows that while VR's immersive nature holds potential for increasing student engagement, it may hinder attention and focus due to its technological complexity. These findings suggest that although VR offers promising opportunities for interactive and immersive learning, further development is required to overcome its limitations and ensure it enhances, rather than detracts from, educational outcomes. The study provides valuable insights for educators, educational technology developers, and policymakers considering the integration of VR into modern educational practices. Ultimately, this research aims to guide the future implementation of VR as an effective learning tool by identifying both its strengths and areas for improvement.

Future VR research in engineering should focus on areas that advance both the technology and its practical applications, ensuring the greatest impact on education, design, and practice. One focus area of continued need to how to use VR to enhance educational experiences. Here, researchers can investigate how VR can create interactive, realistic simulations for teaching complex engineering concepts like fluid dynamics, thermodynamics, or structural analysis. In addition, researchers can explore VR's role in hands-on training for engineering tasks such as welding, machining, or robotics. Also, researchers can study how adaptive VR environments can tailor content to individual learning styles and proficiency levels. Finally, research should be explored for enhancing teamwork skills that enable engineers in different locations to collaborate in VR, manipulating 3D models in real time.

By addressing these areas, VR research in engineering can not only push the boundaries of technology but also empower future engineers to solve complex, real-world problems effectively.

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