Immersive Learning Environment: Investigating Student Engagement, Retention and Learning Outcomes in Using Virtual Reality (VR) and Augemented Reality (AR) in Teaching and Learning

[1]Johan @ Eddy Luaran., [1]Kyra Aqilah Binti Jamal., [2]Jasmine Jain

[1]Faculty of Education, Universiti Teknologi MARA

[2]School of Education, Taylor's University

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ABSTRACT

The study explores how these immersive technologies address challenges in traditional classrooms, such as maintaining student enthusiasm and effective knowledge retention. A meta-analysis reveals a significant positive impact of VR on student engagement, particularly in higher education and immersive VR experiences, affecting cognitive, emotional, and behavioral aspects. The research also examines the key characteristics of VR and AR in education, their applications in various learning domains, and the factors influencing their effectiveness, including the role of immersive experiences, interactive design, and individual learning styles. The study highlights the potential of VR/AR to improve knowledge retention through experiential learning and addresses challenges related to cost, technical support, and content creation. Future research directions are suggested, emphasizing the need for longitudinal studies and investigation into optimal integration strategies. The conclusion emphasizes the transformative potential of VR/AR in revolutionizing education while acknowledging the need for careful consideration of various factors for successful implementation.

Keywords: Virtual Reality, Augmented Reality, Student Engagement

INTRODUCTION

The conventional education system often faces challenges in its work to maintain student enthusiasm, effectively retain information, and achieve the desired learning results. At times traditional classroom settings may not provide sufficient opportunities for interaction and hands- on activities, which makes it hard for students to grasp complex concepts and stay engaged. In addition, the conventional way of teaching does not match all types of people's learning styles; It causes differences in student performance. A problem here is that students in traditional educational settings are often apathetic spectators of the class.

This kind of learning can lead to indolence or non-participation, and communicate the badhabit into future work-related contexts outside school. It is quite possible that where there exists an assessment-orientated education system like this one, the ability to store information and applyknowledge in an effective manner may be weakened. Furthermore, the gap between theory and reality inherent in traditional educational models can also work against applying what you know to everyday life. To cope with these problems, the use of virtual reality (VR) and augmented reality(AR) in immersive learning environments have become a solution in sight. These kinds of interactive, meaningful experiences encourage students' involvement through story-telling techniques that draw them into the material both visually and interactively. Novel sensing mechanisms enable these multilateral, experiential methods of learning to be a trigger for memoryretention as well as facilitator for the application of knowledge.

This paper "Immersive Learning Environment: Investigating Student Engagement, Retention, and Learning Outcomes in VR/AR Education aims to explore how these innovative technologies can address the problems of

student engagement, retention, and learning outcomes. By investigating the effectiveness of VR/AR in education, the research seeks to provide insights into how these technologies can be optimized to enhance the overall educational experience and outcomes for learners.

Immersion learning environments are transforming education by giving students dynamic and interesting learning opportunities. This is especially true for those that make use of VR and AR technologies. Compared to traditional methods, these environments foster a sense of presenceand immersion, enabling learners to explore complex concepts and scenarios in a more impactful and intuitive manner. The interactive nature of VR/AR technologies greatly increases student engagement in these settings. In order to promote deeper comprehension and memory retention, learners actively engage in their educational process rather than being passive recipients of information. VR and AR's immersive qualities have the potential to boost motivation and interest,which will improve the effectiveness and enjoyment of learning.

Another important factor that VR/AR education affects is information retention. Immersionexperiences have been found to enhance memory retention because they involve multiple senses,which strengthens the encoding of information. Better learning outcomes can result from VR/AR'sability to bridge the gap between theoretical knowledge and practical application by simulating real-world applications and offering hands-on experiences.

Technology is advancing so quickly that it is revolutionising many industries, including education. Virtual reality (VR) and augmented reality (AR) are two of the many technological innovations that have the potential to revolutionise traditional classroom experiences. Whereas augmented reality (AR) superimposes digital information on the real world to improve learning through interactive, contextually rich content, virtual reality (VR) offers unique opportunities to engage and immerse students in educational content. The ability of VR and AR to create immersivelearning environments that go beyond the physical confines of traditional classrooms holds the keyto unlocking VR and AR's educational potential. This ability will improve learning outcomes andfoster deeper engagement from students.

By offering immersive, interactive, and captivating learning experiences, these technologies help make abstract ideas more approachable and real. This term paper conducts a thorough analysis of the body of research to determine how VR/AR affects learning outcomes, retention, and student engagement. Understanding how these technologies affect learning outcomes and processes is the main goal, as is identifying possible areas for additional research.

Definition and Characteristics of VR/AR in Education

Virtual Reality (VR) and Augmented Reality (AR) are cutting-edge technologies that have been increasingly integrated into educational settings to create immersive learning environments. Boththetechnologies offer unique capabilities that can transform traditional teaching and learning methodsby making abstract concepts more tangible and learning experiences more interactive and engaging.

Virtual Reality (VR)

VR is a computer-generated simulation of a three-dimensional environment that can be interactedwith in a seemingly real or physical way using special electronic equipment, such as a helmet witha screen inside or gloves fitted with sensors. The key characteristics of VR in education include:

- **Immersion**: VR creates a sense of presence in a virtual world. This immersive experiencecan help students feel as if they are part of the subject matter, which can enhance understanding and retention.
- **Interaction**: VR allows for interaction with virtual objects and environments. Students canmanipulate virtual objects, explore virtual spaces, and perform virtual tasks, which can leadto a deeper understanding of complex concepts.
- **Simulation**: VR can simulate real-world environments and scenarios that are otherwise difficult or impossible to experience in a traditional classroom. For example, VR can simulate historical events, scientific phenomena, or hazardous situations in a safe and controlled manner.

Augmented Reality (AR)

AR overlays digital information onto the real world, enhancing the user's perception and interaction with their real-world environment through devices like smartphones, tablets, or AR glasses. The key characteristics of AR in education include:

- **Augmentation**: AR adds layers of information to the real world, providing additional context and enhancing the learning experience. For instance, AR can overlay anatomical diagrams onto a physical human body model, allowing for an interactive exploration of human anatomy.
- **Accessibility**: AR is more accessible than VR as it can be used with everyday devices suchas smartphones and tablets. This makes AR an attractive option for schools and institutionswith limited budgets.
- **Interactivity**: Like VR, AR allows for interactive learning experiences. Students can interact with digital content in real-time, which can enhance engagement and retention.

Differences between VR and AR

While VR and AR share some similarities, they also have distinct differences that make them suitable for different educational applications:

- **Environment**: VR completely immerses the user in a virtual environment, whereas AR enhances the real world by overlaying digital information.
- **Equipment**: VR typically requires specialized equipment such as VR headsets and motionsensors, while AR can be accessed through common devices like smartphones and tablets.
- **Experience**: VR offers a fully immersive experience, often isolating the user from the realworld, which can be beneficial for simulations and immersive training. AR, on the other hand, allows users to remain connected to the real world while receiving augmented information, which can be useful for on-the-go learning and field applications.

Applications in Education

1. **VR Applications**:
    - **Virtual Field Trips**: VR can take students on virtual field trips to historical sites, museums, and distant geographical locations, providing immersive learning experiences that are otherwise inaccessible.
    - **Simulations and Labs**: VR can simulate scientific experiments and procedures, allowing students to conduct virtual labs and practice skills in a risk-free environment. This is particularly useful in medical and engineering education.
    - **Skill Training**: VR can be used for training in various skills, such as surgical procedures, flying aircraft, or operating complex machinery, by providing a realisticand safe environment for practice.
2. **AR Applications**:
    - **Interactive Textbooks**: AR can turn traditional textbooks into interactive learningtools by overlaying multimedia content, 3D models, and animations onto printed pages.
    - **Language Learning**: AR can enhance language learning by overlaying translations, pronunciation guides, and interactive exercises onto physical objects and text.
    - **Collaborative Learning**: AR can facilitate collaborative learning by allowing multiple students to interact with the same augmented content in real-time, promoting teamwork and problem-solving skills.

Student Engagement

Student engagement plays a crucial role in the learning process by impacting academic performance, motivation,

and perseverance. According to research, the use of VR and AR technologies can greatly increase student engagement by enhancing the interactive and enjoyable nature of learning. In the context of education, engagement is frequently seen as a complex conceptwith behavioural, emotional, and cognitive components. The term "behavioural engagement" describes how students participate in class activities and how they persevere through learning assignments. Students' emotional responses in the classroom, including curiosity, boredom, and anxiety, are all included in the concept of emotional engagement. The degree to which students put effort into their education, use critical thinking skills, and are driven to comprehend difficult concepts is known as cognitive engagement.

A meta-analysis by Chen et al. (2022) found that VR, with an effect size of 0.85, has a significant impact on student engagement, especially in higher education and immersive VR experiences. The results of the analysis showed that VR has a significant effect on cognitive engagement, with immersive VR having a larger effect size than non-immersive VR. The study also showed that VR has a greater influence on procedural knowledge learning and art education.

Behavioral Engagement

Studies have shown that VR and AR can significantly enhance behavioral engagement by makinglearning activities more dynamic and interactive. For instance, the study by Chen et al. (2022) in Chen et al (2024) demonstrated that VR significantly increases student participation and attentionin higher education settings. The immersive nature of VR captures students' interest and keeps them actively involved in the learning process. Similarly, Al-Ansi et al. (2023) discussed how ARapplications in K-12 education led to higher levels of student participation in classroom activities.

Emotional Engagement

VR and AR technologies also positively impact emotional engagement by creating more enjoyableand stimulating learning experiences. The novelty and excitement associated with VR/AR can reduce feelings of boredom and increase students' enthusiasm for learning. Chen et al. (2024) highlighted that VR environments lead to greater emotional engagement due to the sense of presence and realism they provide. This is supported by Al-Ansi et al. (2023), which found that students reported higher satisfaction and motivation levels when using AR tools in their studies.

Cognitive Engagement

Cognitive engagement is arguably the most significantly impacted dimension by VR/AR technologies. By providing realistic simulations and interactive experiences, VR and AR encourage deeper cognitive processing and critical thinking. For example, VR can simulate complex scientific phenomena, allowing students to experiment and observe outcomes in a controlled virtual environment. Chen et al. (2024) had found VR has a large effect size on cognitiveengagement, particularly in education at higher level and STEM fields. The ability to manipulate virtual objects and explore virtual worlds enhances understanding and retention of complex concepts.

Table 1: Analysis of the effect of VR technology on learning engagement

Dimension of Engagement	Number of Studies	Effect Size	95%CI		Z
			LowerCI	UpperCI	
Cognitive engagement	8	0.464	0.296	0.631	5.430***
Emotional engagement	8	0.248	0.018	0.478	2.116*
Behavioral engagement	8	0.458	0.177	0.739	3.192**
Social engagement	7	0.318	0.260	0.482	2.655**

(Source: Chen et al. (2024))

Case Studies and Evidence

In higher education, VR and AR have been used to enhance engagement across various disciplines as shown in

table 2. For instance, in medical education, VR simulations allow studentsto practice surgical procedures in a safe and controlled environment. This not only improves theirpractical skills but also keeps them engaged by providing a realistic and immersive learning experience. Chen et al. (2024) reported that VR has a particularly strong impact on engagement inhigher education, with students showing increased interest and persistence in their studies. In K- 12 education, AR has been effectively used to make learning more interactive and fun. For example, AR applications can bring historical events to life or provide interactive 3D models of biological organisms. Al-Ansi et al. (2023) discussed several case studies where AR tools were used in elementary and secondary schools, leading to higher levels of student engagement and improved learning outcomes. The ability to interact with digital content in real-time makes learningmore engaging and helps maintain students' interest. VR and AR have also been used to enhance engagement in the arts and humanities. For example, VR can create virtual art galleries or historicalreenactments, allowing students to explore and interact with the content in ways that are not possible with traditional methods. Chen et al. (2024) highlighted that VR has a significant impacton engagement in art education, as it provides immersive and interactive experiences that stimulatecreativity and interest.

Table 2 : Moderator analysis of learning engagement

Moderator	k	g	95%CI	QB	p-Value
learner stage				**2.36**	**0.5000**
Primary school	8	0.832	[0.382,1.282]		
Secondary school	3	0.466	[-0.038,0.970]		
Higher education	5	1.158	[0.366,1.949]		
Mixed education	1	0.735	[0.276,1.195]		
VR technology				**1.06**	**0.03**
Immersive	14	0.925	[0.554,1.297]		
Non-immersive	3	0.546	[-0.072,1.164]		
Learning field				**0.89**	**0.64**
Natural sciences,	7	0.847	[0.309,1.385]		
Social sciences & humanities	7	0.743	[0.433,0.953]		
Arts	3	1.338	[-0.155,2.831]		
Knowledge type				**2.85**	**0.041**
Procedural	13	0.971	[0.574,1.368]		
Declarative	4	0.515	[0.166,0.864]		

(Source: Chen et al. (2024))

Factors Influencing Engagement

Several factors influence the effectiveness of VR/AR in enhancing student engagement. ImmersiveVR tends to have a greater impact on engagement compared to non-immersive VR or AR, due toits ability to create a more realistic and interactive environment. The impact of VR/AR on engagement can vary depending on the subject matter. For example, VR is particularly effective in subjects that benefit from simulation and hands-on practice, such as science and engineering. The design of VR/AR learning activities plays a crucial role in determining their impact on engagement. Well-designed activities that align with learning objectives and provide meaningful interactions are more likely to enhance engagement. Individual differences among students, such as their prior experience with technology and their learning preferences, can also influence how engaging they find VR/AR learning experiences.

Retention

Good learning depends critically on knowledge retention. By offering chances for experiential learning that support memory through repetition and practice, VR/AR technologies can increase retention. Studies contrasting VR/AR-based learning with conventional approaches often show higher retention rates in immersive settings.

Particularly in areas of procedural knowledge, VR showed a positive impact on retention in a meta-analysis by Chen et al. (2024), covering studies up until December 2022. The immersiveand interactive character of the learning experiences in VR environments helped to explain the higher retention rates there. These encounters help students to regularly repeat and practise ideas and techniques, so strengthening their memory since they

involve them more deeply.

Moreover, research by Al-Ansi et al. (2023) revealed that VR-enhanced learning environments enable students to retain knowledge longer by involving several senses and so offering a more complete awareness of the subject matter. Medical students who used VR to replicate surgeries, for instance, kept procedural steps better than those who only used textbooks or videos. Multiple senses in VR—visual, auditory, and occasionally kinesthetic—offer a richer and deeper background that helps the material to be remembered.

Furthermore, VR and AR offer chances for experiential learning difficultly obtained in conventional classroom environments. For medical students or complex machinery handling for engineering students, VR simulations can provide experiences that closely reflect real-world scenarios without the real risks. Multiple times in a controlled environment, students can repeat these processes, so enhancing long-term retention and supporting their learning.

The ideas of experiential learning—where learning that actively involves and interacts withstudents is more readily remembered than in passive learning—also help to explain how well VR/AR technologies improve retention. Students in VR/AR environments learn ideas not only theoretically but also practically in simulated real-world scenarios. In an immersive environment, repetition and practice help create strong memory connections, so enhancing the durability of theknowledge in memory.

Moreover, studies on VR/AR environments show that learning in them can help to lower the cognitive load sometimes connected with mastering difficult ideas. VR/AR promotes deeper knowledge and long-term retention by separating these ideas into smaller pieces and letting students interact with each one little by bit. This method not only increases information retention but also helps students apply their knowledge in practical contexts, so improving their capacity and relevance for their education.

Overall, VR/AR technologies show great benefits in enhancing knowledge retention through immersive, interactive, and repetitive learning experiences, according to Chen et al. (2024)and Al-Ansi et al. (2023). This method guarantees deeper knowledge and more efficient application in pragmatic settings in addition to helping students remember material longer.

Challenges and Limitations

Though VR/AR has great promise for use in the classroom, several issues and restrictionsmust be resolved. Widespread adoption can be hampered by technological obstacles including thegreat cost of VR/AR equipment and the necessity for technical support. Integrating these technologies into current courses and making sure they complement rather than divert from learning goals present pedagogical difficulties as well.

Chen et al. (2024) and Al-Ansi et al. (2023) go into great length on these difficulties. Chenet al. (2024) observe that the novelty and possible distractions in VR environments make it challenging to keep student attention. Al-Ansi et al. (2023) underline the need of creating contentthat makes use of the strengths of these technologies as well as the need of sufficient training for teachers to properly use VR/AR tools.

Furthermore, some research on the effect of VR on learning engagement has produced conflictingfindings; factors including cognitive load and user experience affect results Makransky et al., (2019). Thus, to maximise the efficacy of VR/AR learning activities, great design and execution of them are absolutely vital.

Future Directions

The future of VR/AR in education is promising, with emerging trends indicating greater integration and innovation. Advances in technology are making VR/AR more accessible and affordable, while research is exploring new pedagogical approaches to leverage these toolseffectively.

Recommendations for future research from both Chen et al. (2024) and Al-Ansi et al. (2023) include longitudinal studies to assess the long-term impact of VR/AR on learning outcomes, comparative studies across different educational levels and subjects, and investigationsinto the most effective ways to integrate VR/AR into diverse

learning environments.

CONCLUSION

The integration of VR and AR in education has the potential to revolutionize the learning experience by enhancing student engagement, improving learning outcomes, and addressing diverse learning styles. The immersive and interactive nature of these technologies creates engaging and effective learning environments that transcend traditional pedagogical boundaries. However, successful integration requires careful consideration of technical, pedagogical, and logistical factors. As VR and AR technologies continue to evolve and become more accessible, their role in education is likely to expand, offering exciting possibilities for educators and learnersalike.

Future research should continue to explore the long-term effects of VR and AR on studentengagement and learning outcomes, as well as the scalability and cost-effectiveness of these technologies in diverse educational settings. Additionally, the development of best practices and guidelines for VR and AR integration into curricula is essential to maximize their potential whilemitigating challenges.

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