Engaging Science Learners at Disadvantaged schools in South Africa in the Use of Culturally-Anchored Virtual Reality Simulations for Inquiry-based Learning

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Abstract: This study explores the perceptions and experiences of high school learners at historically disadvantaged schools in South Africa who engaged with Culturally-Anchored Virtual Reality Simulations (CAVARS) for science learning. Using a qualitative case study approach, data were collected through group interviews following a classroom-based intervention. Thematic analysis revealed key themes: emotional engagement, enhanced conceptual understanding, preference for experiential learning, cultural relevance, and the desire for equitable access to educational technology. Implications are discussed in terms of pedagogical practice and the integration of immersive technologies in resource-constrained educational contexts.

Keywords: virtual reality simulations; science inquiry-based learning; disadvantaged schools

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Introduction

The lack of culturally relevant resources for science learning means school learners in South Africa and other African countries are disadvantaged in their experience of practical inquiries that form the cornerstone for effective science learning. This has seriously affected school science achievement of South African learners, with the country often performing poorly in international benchmarking tests such as Trends in International Mathematics and Science Study (TIMSS) and national high stakes assessments. The Centre for Advanced Learning Technologies in Science, Technology, Engineering, Arts and Mathematics (CALTSTEAM) at the University of Johannesburg embarked upon a project to develop Culturally-anchored Virtual and Augmented Reality Simulations (CAVARS) to support situated and culturally relevant learning of

science. Emerging technologies such as Virtual Reality (VR) and Augmented Reality (AR) are rapidly transforming the educational landscape. These tools offer immersive and interactive experiences that can make abstract scientific concepts more tangible through inquiry-based learning where learners are actively engage in exploring scientific questions, problems, or phenomena (NRC, 2000). While educational applications exist in VR and AR, there are limited resources in these technologies where African cultural knowledge is infused. The development of CAVARS addresses a void in the African science education for such resources

Figure 1. Examples of CAVARS

Theoretical framework

This study is guided by two interrelated theoretical lenses: Kolb's Experiential Learning Theory (1984) and Multimodal Learning Theory (Moreno & Mayer, 2007). Kolb's theory emphasises learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualisation, and active experimentation. In this context, VR and AR tools act as enablers of concrete experiences, facilitating deeper engagement with scientific concepts through active interaction. Multimodal learning theory underscores the cognitive benefits of presenting information through multiple sensory modalities, including visual, auditory, and kinesthetic inputs. The integration of visual (AR interfaces), auditory (simulated sounds), and kinesthetic (interactive manipulation) modes in this study supports diverse learning preferences and enhances conceptual understanding.

Methodology

A qualitative case study design was used to explore the experiences of high school learners in the provinces of KwaZulu-Natal, Limpopo and Northern Cape who experienced VR and AR in a science classroom. Data were collected through informal group interviews conducted immediately after the intervention. The intervention featured CAVARS of Umqombothi (Grade 8 Chemical Reactions); Cultural drumming (Grade 10 Sound); and Phases of the moon (Grade 7 Historical development of astronomy and Grade 8 Solar System), viewed through both VR headsets and AR-enabled tablets. The participants were Grades 8 and 9 learners from historically disadvantaged high schools situated in rural and semi-rural communities in South Africa. Data were transcribed and analysed thematically. Initial codes were derived inductively, then grouped into themes based on recurring patterns.

Findings

Theme 1: Emotional Engagement and Curiosity Learners expressed excitement and curiosity, highlighting the novelty of the experience. The following interview excerpts highlight this experience.

It was so exciting and unique. I would like to have experience to learn more.
It is something else, and like another world.

Theme 2: Conceptual Understanding through Visualisation

Learners noted that VR/AR helped them understand scientific phenomena like sound waves. The learners expressed this affordance as follows:

I didn't know about waves, now I know types of waves
I saw that sound travels through small particles.

Theme 3: Learning Preferences and Modalities

Many students identified as kinesthetic or visual learners, stating that the technology allowed them to better grasp the concepts. This is evidence below from these excerpts:

I learn by doing things and so this was good for me.

Watching it helped me understand better than reading notes.

Theme 4: Cultural Relevance and Identity

CAVARS resonated culturally with the background of learners. The learners took some pride in recognizing that their culture was being recognized through the simulations. They also appreciated that cultural practices such as the making of Umqombothi was underlined by chemical processes and chemical reactions. This is evident below:

I learned how to make Umqombothi. It's part of our culture.
I didn't know drumming and the beer had science in them.

This intersection of science, technology and cultural knowledge sparked interest and pride among learners.

Theme 5: Desire for Equitable Access to Technology

Learners called for broader access to these tools at their schools. They believed that it could make a difference to how they learn science.

You must tell our principal to buy iPads for school.
Learning science with iPads and the headsets is fun.

Discussion

The findings affirm that immersive technologies can create emotionally engaging and conceptually meaningful science learning experiences. Learners' preference for hands-on and visual learning aligns with multimodal learning theories and underscores the need for inquiry-based learning experiences. The cultural dimension suggests that blending scientific content with indigenous knowledge systems may enhance learner identity and engagement.

The study also reinforces Kolb's experiential learning cycle, as learners engaged in experiences that led to reflection, conceptual understanding, and a desire for future

engagement. The need for equitable access to immersive technologies remains a significant barrier that must be addressed for broader implementation.

Conclusion

This study highlights the transformative potential of VR and AR in supporting science education in under-resourced schools. By enabling learners to visualise abstract concepts, engage emotionally, and connect culturally, immersive technologies present a promising avenue for enhancing science learning. Future research should explore longitudinal impacts and strategies for sustainable implementation.

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