GAME-BASED LEARNING WITH AUGMENTED REALITY

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ABSTRACT

My work contributes to the field of Human-Computer Interaction (HCI) in Science, Technology, Engineering, and Mathematics (STEM) education by providing a theorized understanding of the benefits of integrating Augmented Reality (AR) technology into educational tools. Addressing gaps in AR games for education, I conducted two main studies to explore the impact of AR on learning outcomes and usability across different platforms. My findings highlight improved knowledge scores with AR game training, particularly on HoloLens devices. Additionally, the exploration of immersive Virtual Reality (VR) and AR interfaces for matrix transformations reveals increased comprehension. Based on my findings, my work recommends further exploration of AR games with alternative modalities to respond to diverse learning styles, presenting valuable insights for the design of effective educational technologies.

Keywords: Augmented Reality, Game-based Learning, STEM education, chemistry, matrix transformation.

1 INTRODUCTION

The various non-interactive learning tools in education raised concerns about student engagement, particularly in the STEM fields [1]. STEM education's emphasis on critical thinking and creativity tools that deliver content and actively involve learners in the educational process. The Cone of Learning theory confirms that active participation sustains better retention of information, setting the stage for the integration of interactive tools in the learning environment [2, 3]. Game-based Learning (GBL) , a strategy that combines gaming principles into educational contexts, offering a method for engaging and interactive learning experiences [4]. STEM disciplines, including chemistry and mathematics, have controlled the power of GBL to simplify complex concepts, integrating game rules and experiences into the learning process [5]. AR , with its ability to enhance the real-world environment by overlapping digital elements, emerges as a transformative technology in education [6]. The integration of AR into education brings a diverse array of platforms, including traditional desktop, Head-mounted Display (HMD) , and handheld mobile devices. The variety of platforms and interaction techniques, however, remains an empirical question, dependent on the learning task, context, and learner preferences [7]. The effectiveness of AR in education lies in its application to learning content and in understanding how it influences learning outcomes and user satisfaction. While existing literature explores the impact of AR in STEM education from a learning outcome perspective, there is a notable gap in understanding the usability and learning outcomes from the perspective of application developers, game designers, and learners. This work addresses the gap, with a focus on learner experience, by exploring the interaction modes and platforms for AR games in chemistry and matrix transformation education. The goal is to investigate how different AR technologies applied to GBL influence learning outcomes and user satisfaction, identifying the optimal learner interface for AR game training. The overarching thesis of my work is *that The integration of AR /VR learning tools, coupled with diverse game platforms and modalities, can elevate educational outcomes by augmenting student engagement, refining learning performance, and nurturing spatial cognition.*

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2 STUDIES

Study 1: Multi-Platform Comparison of AR Game Training The primary objective was to conduct a multi-platform comparison of AR game training, specifically evaluating usability and learning outcomes across desktop, tablet, and HMD platforms. The study involved designing and developing a periodic table-focused AR game, emphasizing realism, task complexity, and user engagement. Usability tests were implemented to assess the user experience and knowledge retention on different platforms, with data collection including user feedback through surveys, interviews, and user performance. The results indicated that overall, AR games on all platforms led to improved chemistry knowledge test scores, showcasing increased learner engagement and comprehension. Notably, multi-platform comparison highlighted that the HMD platform, HoloLens devices, provided the most positive learner experience and resulted in improved knowledge test scores. However, challenges were identified, particularly the difficulty of use and limitations of input/output techniques, especially for participants unfamiliar with HMD devices. These findings contribute valuable insights into the effectiveness and challenges associated with different platforms in AR game training contexts. Building on these findings, the subsequent research planned to explore the impact of alternative modalities, tactile versus auditory, on user experience and learning outcomes within AR games. This investigation seeks to provide a deeper understanding of how incorporating diverse sensory interactions can enrich the learning experience, offering valuable insights for the ongoing design and development of educational tools.

Study 2: Immersive VR and AR Interfaces for Learning Matrix Transformations This study involved the exploration of immersive VR and AR interfaces, specifically focusing on learning matrix transformation concepts. The primary objective was to understand the usability and learning outcomes associated with these interfaces. The study involved the development of immersive VR and AR interfaces for learning matrix transformations, emphasizing interactive and visually engaging elements. Usability tests were conducted, concentrating on comprehension and user satisfaction. The data collection process included user feedback obtained through observations, interviews, and surveys, along with user performance measuring comprehension and engagement. The results indicated that the exploration of immersive VR and AR interfaces for learning matrix transformations led to increased comprehension among users, together with positive feedback on usability. The integration of interactive and visually engaging tools was found to be beneficial in facilitating the learning process on the complex topic of matrix transformations. This study contributes valuable insights into the effectiveness of immersive interfaces in enhancing understanding and engagement, especially in educational contexts involving intricate subjects like matrix transformations.

3 DISCUSSION AND CONCLUSION

The findings from conducted studies show the promising role of AR in educational settings, offering insights for learners, designers, and researchers. The positive outcomes observed in Study 1 emphasize the potential of AR technology to elevate learning experiences, supporting increased engagement and comprehension. However, the platform-specific challenges identified, particularly for users unfamiliar with HMD devices, emphasize the importance of considering user familiarity and comfort in designing and implementing AR applications. Moreover, the exploration of alternative modalities in the Study 1 plan highlights the variability in user preferences, advocating for a diversified approach to accommodate different learning styles. While challenges, such as usability concerns, were identified, they also present opportunities for further research and refinement of AR technologies. Overall, these findings contribute valuable insights to the integration of AR in education, emphasizing the need for approaches that address platform-specific considerations and cater to the diverse preferences of learners. In conclusion, my work provides a comprehensive exploration of the integration of AR in the educational context, specifically focusing on its application in game-based learning. The conducted studies show the positive impact of AR on learning outcomes and user experiences, emphasizing its potential to enhance engagement and comprehension. The identified challenges, particularly in terms of platform-specific issues and user preferences, offer valuable insights for future developments

in AR educational tools. Leveraging these findings to refine AR applications is crucial, considering user familiarity, comfort, and diverse learning styles. The continuous advancement of AR technologies holds great promise for transforming the educational perspective, and my work contributes the empirical evidence and practical considerations for the effective integration of AR in educational practices.

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