Mapping the Impact of Augmented Reality (AR) and Virtual Reality (VR) in AEC Education

(Technical Paper)

Augmented Reality (AR) and Virtual Reality (VR) in the Context of Education: Transforming Learning in the Digital Age

(STS Paper)

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The fusion of education and technology has led to an educational revolution, expanding conventional learning boundaries. At the forefront of this transformation are Augmented Reality (AR) and Virtual Reality (VR), technologies poised to reshape pedagogy and the overall educational experience. These digital innovations seamlessly integrate information into the real world, providing students with immersive and interactive learning experiences (Billinghurst et al., 2015; Wu et al., 2013). My research explores the impact of AR and VR technologies on learning processes and the implications for educational institutions. It delves into teaching effectiveness, accessibility, affordability, and challenges associated with integrating these technologies into traditional classrooms, potentially revolutionizing education.

AR technology merges digital elements into the tangible world, first proposed by Boeing employees in 1990 (Cevikbas et.al, 2023). On the other hand, VR offers a wholly immersive experience, with roots dating back to Aldous Huxley's novel 'Brave New World' published in 1932 (Cevikbas et. al, 2023). The evolution of AR/VR, closely intertwined with device support, has transitioned from heavy computers to smartphones and tablets, with the emergence of Head-Mounted Displays (HMDs) providing even more immersive experiences.

Technical Project

AR/VR technologies find applications in the architecture, engineering, and construction (AEC) industry. The AEC industry has witnessed transformative advancements in technology, but despite extensive research on the positive impacts of AR and VR on students' understanding, limited research has explored the status of these technologies in the AEC industry. Looking at systematic analysis of affordances and limitations of immersive AR simulations, serves as a methodological guidepost for my own research (Dunleavy et al., 2009). To bridge this gap and provide a valuable reference for researchers and educational institutions, it is important to classify applications in AEC education and quantify their effectiveness.

My technical project aims to address this gap by classifying existing applications and quantifying their effectiveness, providing a valuable reference for researchers and educational institutions. By developing a taxonomy to categorize applications based on their functionalities, target audience, and educational objectives and creating a comprehensive catalog of classified AR and VR applications that include detailed descriptions and features, my technical project will contribute valuable insights into the landscape of AR and VR applications in AEC education. The web-based platform will include search functionalities, detailed application profiles, and user reviews integrated with an online assessment tool that evaluates learning outcomes of students who have used specific AR and VR applications. By developing performance metrics, skills improvement and practical application of knowledge will be evaluated. The classification and effectiveness evaluation will provide recommendations and guide educators, researchers, and institutions in selecting and implementing these technologies, ultimately enhancing the quality of education in the AEC domain.

STS Topic: AR and VR in the Context of Education

AR and VR have a transformative impact on education, providing immersive learning experiences for students. Research shows that "Nearly 30% of the U.S. population already uses AR monthly," (Turner et. al, 2022). These technologies can be utilized in creating realistic environments for various educational applications. While AR and VR technologies share a close connection, they employ distinct methods for engaging with reality and virtual experiences (Tan et.al, 2022). AR superimposes virtual elements onto the physical world, allowing users to interact with a blend of real and virtual content. In contrast, VR is designed to immerse users fully in a virtual environment, making them a part of the digital world. In higher education, medical students are able to practice surgeries in VR and biology students can engage with various organisms through technological simulations. As a more specific example, Morehouse College, a Historically Black University (HBCU), created four VR programs, known as Morehouse in the Metaverse, where professors taught courses in VR on a digital twin campus created in partnership with VictoryXR, transforming classes into a virtual format during the pandemic. Another example, Arizona State University (HSI), partnered with Dreamscape to create a nine-module VR series for biology lab students, simulating a zoo, and professors noted higher engagement and improved grades for students using VR compared to the traditional in-person curriculum (Turner et. al, 2022).

While programs like these enhance engagement, primarily in the AEC industry, there are existing challenges related to accessibility and affordability that prevent the widespread adoption of the technologies in schools, leading to disparities that disadvantage some students in their preparation and job market prospects due to a lack of economic and network resources. Community colleges face systematic underfunding, hindering the adoption of AR/VR infrastructure due to high costs. Accessibility and affordability are crucial considerations when implementing AR and VR technologies in education as they play a significant role in promoting equitable learning opportunities.

Access refers to the availability and opportunity for students and educational institutions to use these technologies, involving factors such as infrastructure, device availability, and technological support. Limited access can create disparities in educational experiences; thus, addressing access challenges is essential for providing equal learning opportunities to all students. Affordability considers the cost implications of implementing AR and VR solutions including the cost of devices, software, and maintenance. Sustainable implementation requires considering long-term costs. I believe it is important to explore open-source AR and VR platforms that can reduce software licensing costs, and implement strategies for sharing these technology devices to maximize their use across students.

Research Question and Methods

The core question driving my research is: *"In what ways do augmented reality and virtual reality technologies impact learning processes particularly in the AEC industry, and what are the implications for educational institutions?"* I believe this question encapsulates the multidimensional nature of the study, evaluating the effectiveness of AR and VR in enhancing teaching instructions while exploring issues of accessibility and affordability, and it explores the

challenges and opportunities presented by the integration of these technologies into traditional learning approaches (Dalgarno & Lee, 2010).

I will begin my research with an extensive literature review, providing insights into the current state of AR and VR technologies in education, and analyzing peer-reviewed articles, case studies, research reports, and academic journals focused on educational technology. Using keywords such as “AR applications for learning”, “VR-based instruction”, “integration”, “student engagement”, “accessibility and affordability”, and “AEC industry” when searching for resources related to my research topic will help refine my search. I will lay a solid foundation for understanding of the educational landscape’s current state while identifying gaps and emerging trends. One systematic review I found aims to discern trends in educational augmented reality studies, providing an overview of the current state of research in this domain (Sirakaya & Alsancak Sirakaya, 2018). The analysis includes a comprehensive review of peer-reviewed articles, shedding light on the methodologies, focus areas, and emerging patterns within the field. It reveals distinct trends that bear implications for our research and analyzes methodologies employed in AR studies offering valuable insights into the preferred approaches within the educational context. Understanding these methodologies informs my own research design, ensuring alignment with established practices and methodologies that have proven effective; it identifies key focus areas within Educational Augmented Reality Studies, ranging from the impact on student engagement to the effectiveness of AR applications in enhancing learning outcomes. By incorporating these focus areas into my exploration, I will have a more targeted investigation, addressing specific dimensions that have been central to recent research in the field. My exploration gains a more informed and targeted approach by aligning with the identified trends, methodologies, and focus areas in the review.

I will use meta-analyses that examine the overall effect and the impact of selected instructional design principles concerning Virtual Reality-Based Instruction (VRBI), for instance; one such meta-analysis revealed that games, simulations, and virtual worlds proved effective in improving learning outcome gains (Merchant et al., 2014). This finding aligns with my initial statement regarding the potential of AR and VR to revolutionize traditional learning settings and shed light on crucial instructional design principles that significantly influence the effectiveness of VRBI. I will also be looking at the Horizon Report to help my research gain a temporal dimension, allowing me to situate AR and VR within the broader narrative of educational technology evolution. The identification of key trends and challenges in 2015 shown in the report serve as a reference point for assessing how AR and VR align with or deviate from the trajectories anticipated at that time (Johnson et al., 2015). My exploration will benefit from a comparative analysis, scrutinizing the predictions and trends outlined in the 2015 K-12 Edition against the current state and prospects of AR and VR in education and enriching the understanding of the interaction between technological foresight and actual implementation.

My research also incorporates a primary data collection phase. I will conduct interviews with key stakeholders in the AEC industry with direct experience in implementing AR and VR technologies in educational settings. The research team at UVA has developed various AR/VR projects working in data-driven mixed reality environments, and to support their research and explore the impact of alternative design solutions on human behavior and decision-making, the

team has established the Omni-Reality and Cognition Lab (ORCL) with support from the UVA Engineering School (Heydarian et. al, 2020). I plan to meet with and interview the core researchers in this team–Professor Arsalan Heydarian and PhD students Amir Ashrafi and Xiang Guo–to gain their perspectives and enable me to uncover the nuances of these technologies' impact on learning.

Key Texts

Billinghurst and coauthors provide a comprehensive overview and analysis of the field of AR and conduct a thorough survey covering the historical development, key concepts, technological foundations, application domains, and emerging trends within the realm of AR. This piece serves as a foundational resource for understanding the technological landscape. By offering insights into the evolution and current state of AR, the article becomes a crucial reference for examining the implications of AR in educational contexts. It provides a basis for understanding the affordances and limitations of AR technology, which is essential for the STS project's goal of classifying and quantifying the effectiveness of AR applications in the architecture, engineering, and construction (AEC) education sector. The survey contributes valuable insights that aid in navigating the complex intersections between technology, education, and societal systems.

Dalgarno and Lee explore the learning affordances of 3-D virtual environments, providing an analysis of the educational opportunities presented by these immersive technologies. They identify and understand the opportunities for action and learning offered by 3-D virtual environments in educational settings. The authors delve into the various aspects of learning, such as collaborative interactions, engagement, and knowledge construction, within the context of 3-D virtual environments. By examining the affordances of 3-D virtual environments, they lay a conceptual groundwork to understand the impact of AR and VR on learning processes, effectiveness, and challenges in architecture, engineering, and construction (AEC) education. The theoretical frameworks and research outcomes presented in this resource provide a valuable reference for evaluating the potential educational benefits of AR and VR applications in the AEC domain.

Johnson and coauthors report an in-depth analysis of emerging technologies and their potential impact on K-12 education. It identifies key trends, challenges, and technologies that are anticipated to shape the educational landscape in the near future. The report discusses the adoption of various technologies, including AR and VR, providing insights into their expected time frames for widespread implementation. This resource is highly relevant to the STS project on AR and VR technologies in education, as it offers a historical perspective on the technological trajectories and foresight in educational technology. By investigating the predictions and trends outlined in the 2015 report, the STS project gains valuable context for assessing how AR and VR align with or deviate from the anticipated trajectories. This comparative analysis enriches the understanding of the dynamic interplay between technological foresight and the actual implementation of AR and VR in education.

Merchant and coauthors research the overall impact and effectiveness of Virtual Reality-Based Instruction (VRBI) on learning outcomes in both K-12 and higher education settings.

Their meta-analysis explores the positive impact of VRBI, specifically focusing on the efficacy of games, simulations, and virtual worlds in improving learning gains. The study reveals that these immersive technologies have proven to be effective tools in enhancing student performance and provides insights into the instructional design principles that significantly influence the effectiveness of VRBI. Understanding the factors that contribute to successful learning outcomes in virtual environments is crucial for informing the exploration of AR and VR applications in education, aligning with the broader goal of the STS project to assess the impact and potential of these technologies on student engagement and learning.

Conclusion

By blending technical expertise with socio-cultural insights, my research offers a comprehensive overview of how AR and VR technologies are revolutionizing student engagement and learning in the digital age. My prospectus outlines the technologies' rapidly increasing impact, underscoring their significance, historical development, and the need for in-depth research in specific domains like AEC education. It identifies trends, methodologies, and focus areas within educational AR and VR studies, incorporating insights from meta-analyses and trend reports to ensure a holistic exploration of the research question. As the educational landscape continues to evolve, my research aims to illuminate the path ahead, where technology and pedagogy converge, creating a brighter future for learners of all ages.

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