Research Output Journal of Biological and Applied Science 3(3):31-35, 2024

ROJBAS Publications **ONLINE ISSN: 1115-9200**

https://rojournals.org/roj-biological-and-applied-science/ **PRINT ISSN: 1115-6120**

The Role of Augmented Reality in Enhancing Engineering Education

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ABSTRACT

This review investigates the use of Augmented Reality (AR) in engineering education, emphasising its revolutionary influence on learning and teaching approaches. Augmented reality (AR) layers digital components onto real-world settings, creating an immersive and dynamic platform that enhances students' comprehension of intricate engineering principles. This paper utilises case examples from higher education institutions such as TalTech, where augmented reality (AR) and virtual reality (VR) technology have been integrated into workshops and laboratories, leading to a notable improvement in student achievement and involvement. Notwithstanding the obstacles and restrictions, such as technological limits and difficulty in creating information, the advantages of augmented reality (AR) in education, especially in promoting practical skills and theoretical comprehension, are significant. The review finishes by suggesting ways to broaden the use of augmented reality (AR) in engineering education. These suggestions include establishing partnerships with industry stakeholders to guarantee that the curriculum remains relevant and that technology continues to progress.

Keywords: Augmented Reality (AR), Engineering Education, Virtual Reality (VR), Immersive Learning, Educational Technology.

INTRODUCTION

Traditionally, an engineer is educated on concepts applicable to his/her specialization. With the advent of virtual environments came the opportunity to enhance learning using modern day technology, but so far not all disciplines have integrated augmented reality learning. With tedious work processes and crucial tolerances, engineering trades have a high learning threshold. The ability to explore fundamentals using augmented/virtual reality environments greatly enhances understanding. With the continuation of adapting trade education to augmented reality, presented is an enhanced engineering education, utilizing benefits of AR perception and 3D viewing. The coexistence of visual and haptic evokes the feel of "doing it for real". Several levels of AR and VR were integrated to education at TalTech, including a basic Android application viewed on a smartphone to AR glasses worn in workshops and labs, or VR headsets simulating the same places. The latter allows students to practice anywhere and at any time. Results are drawn from workshop supervisors' posts and opinion surveys and student performance and surveys in workshops where AR/VR had been applied vs institutions that haven't. The results show that by utilizing AR and VR, students receive a greater theoretical foundation and control over different technologies, yielding a 10-15% increase in performance. Current education is understaffed, while AR/VR requires less supervision. Students prefer the AR/VR models of education and consider them a necessity in the modern world. Future work entails expanding the utilization of AR/VR in the remaining subjects with high learning thresholds. Digital models should also be co-developed with industrial partners to better keep up with the current technology at work [1, 2].

FOUNDATIONS OF AUGMENTED REALITY

Augmented reality (AR) overlays digital images, sounds, and haptic feedback onto the real world through a camera's field of view. AR revolutionizes human-computer interaction and has potential in education, particularly in engineering. Engineers often lack practical knowledge of engineering structures, but AR systems can help bridge this gap by providing a supervised-data approach to learning about concrete bridges and structural concepts. This article presents the design of an AR application for bridge education and a mockup framework for educational institutions. It also discusses ideas for expanding on these concepts and potential improvements using supervised machine learning [3]. As a combination of the virtual and physical worlds, AR systems can be used as an educational tool to overlay virtual information—such as 3D animations, pictures, or text—to assist users in learning a particular subject. The World Wide Web is full of rich content that can be used in AR applications, but currently, it is only accessible through 2D displays. There is an ongoing interest from researchers and developers in bringing such web-based virtual content to AR applications. The first educational AR system is experimentally evaluated using a low-cost AR platform with straightforward design and implementation. The user study has given directions for possible improvements and indications that web AR systems can act as a complementary educational medium [4]. AR technologies are widely used as information systems to help users understand massive physical objects. There are many different kinds and setups of AR systems. Some types of AR implementations are projection-based AR, video see-through AR, optical see-through AR, and instrumented approach AR. There is also another way to classify AR systems based on their common setups. Some systems require head-mount displays to be worn on the head, while other systems use monitors, walls, or tablets as display media. This lecture explores AR systems that do not overlook or hide the physical world and others that are built on other types of medium. Some basic design issues of the projection-based mixed-reality environments are also addressed. Special focus is put on the low-cost design of AR systems using projectors as the only hardware needed to augment physical objects [5].

INTEGRATION OF AUGMENTED REALITY IN EDUCATION

Augmented reality is an evolving technology that integrates synthetic entities into the real world. The combination is normally shared based on invariability in time and space. Moreover, it is a reality-based display system that allows users to view and interact with a combination of a physical and virtual environment [6]. Augmented reality has potential in education for visualization of abstract concepts and adaptive learning. This technology combines 3D objects with background images based on position and perspective. Recent research shows AR's potential in education. A low-cost system integrates AR concepts and free software for high-quality objects. A prototype was tested in a high school physics experiment, providing a cheaper alternative to commercial AR installation. A 2D graphical AR system was developed using Macromedia Flash and stereo-based calculation. 3D objects were rendered with multi-construct software. Real-time processing used a webcam image without filtering or complex algorithms [7]. Furthermore, an experimental investigation into the modeling characteristics of augmented reality-based visualization systems on the teaching mechanisms of latent heat and viscosity mass transfer systems was conducted. In addition, the modeling characteristics of two types of experimental systems with one or more visualized methods were studied. A round copper block submerged in water was used to observe the temperature change process, while liquid sugar and coloring chemicals dissolving in water were used to analyze the mass transfer process. The emphasis of this research is on the AVCI, visualization technique, system design, and experimental arrangement. Although the MELT processes of latent heat and mass transfer systems may be different, similar modeling characteristics will be obtained in terms of temperature and concentration distribution under otherwise the same conditions [8]. Research findings indicated that augmented reality has great potential in the education field. In engineering education, visualization of engineering concepts may help students improve their understanding of the concepts. 3D computer modeling allows accurate visualization of engineering concepts. However, 3D models are not available for all engineering concepts. In this regard, a low-cost augmented reality system is presented in this research to help visualize nonavailability engineering concepts in teaching and learning practices [7].

BENEFITS OF AUGMENTED REALITY IN ENGINEERING EDUCATION

The integration of augmented reality (AR) technology in engineering education can provide a multitude of benefits that enhance both learning and teaching experiences. Augmented reality revolutionizes the process of visualizing and understanding complex engineering concepts by superimposing computer-generated graphics and other sensory stimuli on the user's real-world environment. Such a state-of-the-art immersive technology can be utilized in various forms of educational delivery, from fully immersive simulation to mobile applications. It opens up a brand-new world of information visualization possibilities. Students can experience vivid 3D models in the classroom and at home, and improve their understanding of complex engineering concepts. Fortunately, for the ease of visualization, there already exist numerous easy-to-use AR packages and tools such as Bubble-Scope, which allow educators to easily create and share interactive 3D content without much time or programming knowledge. It brings completely new augmented experiences to the traditional PowerPoint presentation and textbook, allowing a better grasp of engineering knowledge [7]. Engineering education faces challenges in teaching complex concepts due to their abstractness, multi-dimensionality, and invisibility. Traditional teaching aids like textbooks or illustrations are often difficult to understand, resulting in a weak foundation for further studies. Augmented reality (AR) technology offers new possibilities in engineering education by incorporating state-of-the-art, easily accessible features. While AR applications have seen widespread use in various industries, its potential in education, particularly engineering education, is still relatively unexplored. This presents an exciting new frontier for research and development, driven by increased accessibility and affordability [9]. Augmenting reality with information visualization serves as an innovative and anti-passive approach in the complex world of engineering education. Such new artificial realities resulting in experiences and learning that cannot be fully replicated in either the real or virtual worlds alone will give students unprecedented insights and advantages. Meanwhile, an enhanced learning experience, engagement, and interaction will help them actively probe and explore the environment instead of merely consuming the information presented. An evolving and multi-faceted viewpoint of the same engineering object will provide better context and completeness, significantly improving the comprehension of the massive and complex engineering knowledge. Hence, AR technology can help both educators and students tremendously [10].

CHALLENGES AND LIMITATIONS

Despite the promising applications of augmented reality for engineering education, there are notable challenges and limitations to its implementation. First, as presently developed, AR content is limited primarily to visual and auditory stimuli. Although mixed-reality interactions, such as touch-feedback devices, can facilitate kinesthetic forms of engagement, the physical resources necessary for exploring such devices might act as obstacles to their usage (e.g., needing space to install actuators) [11]. It is difficult to create augmented assets that overlay on real-world objects like ID badges, circuit boards, and pipes. AR applications rely on fiducial markers or spatial mapping, which has limitations indoors and with large objects outdoors. Currently, non-developers face challenges creating AR augmentations without extensive programming. However, there is growing interest in easy-to-use solutions for non-programmers [12]. Technical limitations of present smartphones/devices can also inhibit equation complexity, prohibit AR-assisted feedback, and affect understanding ease. Moreover, multiuser interactions became problematic as the technology, reflection, and resource management became complicated enough to distract users from the goal of the demonstration. The demonstrations were also influenced by the experience and training of the students. For example, M1 toughness tests took under a minute, while A5 tensile tests took 2-3 minutes. It is hoped that students will reinforce key concepts in the rationale behind the experiments as experience with the technologies grows. It may also be reasonable to schedule fewer experiments within the same period. However, it should be acknowledged that some aspects, like planning, turn-taking, or attentiveness, may be compromised with very young or inexperienced users [13].

CASE STUDIES AND BEST PRACTICES

Several universities globally are integrating AR content in their curricula, showcasing its innovative potential. This section outlines four compelling case studies, illustrating how AR enhances engineering education through creativity and technical skills development [14]. At the University of Blas Pascal, Argentina, the use of AR in Computer Graphics and Image Processing courses fosters creativity and design skills. The AR project, focused on engineering mechanics, allows students to visualize complex machines and structures in a 3D augmented environment. A devices case is under development, where physics laws can be explored through superposition. Promising results in knowledge acquisition and engagement levels have been reported [15]. The Robotic Engineering Program at California State University, Long Beach, USA, employs AR in safety and industrial robotics courses, improving awareness and understanding of hazardous equipment. 3D AR modeling is used to aid students in developing programmed safety features for industrial equipment. Positive changes in climate and learning effectiveness, as well as acceptance of AR for future education efforts, were noted [16, 17, 18]. A pilot project at North Carolina State University introduces an AR/VR lab into a first-year engineering design course. The lab allows students to improve project presentations with AR/VR content, enhancing communication and problem formulation skills [19, 20]. The project aims to explore AR/VR deployment in an engineering education context and determine its impact on student learning [17]. At Purdue University, USA, AR is applied in Thermodynamics Laboratory courses, aiding students in comprehending the operation of experimental apparatuses on a physical level. Students use AR to visualize thermal and hydraulic energy transfers, interpret measurements, and analyze uncertainty. Evaluation considers pedagogical, implementation, and software aspects [18, 19, 20].

CONCLUSION

The integration of Augmented Reality in engineering education represents a significant leap forward in enhancing both the teaching and learning experience. By providing an immersive and interactive environment, AR facilitates a deeper understanding of complex engineering concepts, leading to improved student performance and engagement. The case studies demonstrate the effectiveness of AR in various educational settings, showing its potential to revolutionize traditional education models. However, challenges such as technical limitations and the need for user-friendly content creation tools must be addressed to fully realize AR's potential. Future work should focus on expanding AR applications across all engineering disciplines and fostering partnerships with industry to keep pace with technological advancements. AR is not just an educational tool; it is a necessary component of modern engineering education that prepares students for the evolving demands of the industry.

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CITATION: Mwaura Maina J. The Role of Augmented Reality in Enhancing Engineering Education. Research Output Journal of Biological and Applied Science, 2024 3(3):31-35.