Virtual Reality and Its Applications in Engineering Education

Group 3

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Virtual Reality (VR) technology has rapidly evolved over the past few decades and has been widely used in various fields, including engineering education. The use of VR in engineering education has gained popularity due to its ability to provide an immersive and engaging learning experience for students. VR enables students to interact with virtual objects and environments, allowing them to explore complex concepts and scenarios in a safe and controlled environment.

Introduction

Virtual reality (VR) technology has emerged as a promising tool for enhancing engineering education. This technology provides students with immersive and engaging learning experiences that can improve their spatial visualization skills, problem-solving skills, and understanding of complex concepts. VR can be used for simulation-based training, allowing students to experience realistic scenarios and practice their skills in a safe and controlled environment. Additionally, VR can be used to visualize complex engineering concepts and designs, enabling students to better understand and apply theoretical knowledge to real-world problems.

VR in Engineering Education

Engineering domains using VR

Virtual Reality has applications in almost every engineering discipline. Majorly it is being used in civil engineering (Wang et al., 2021) for 3D modeling of construction sites and building strategies. The use is almost as vast in mechanical engineering as well. Electrical engineering and industrial engineering are not far behind either. Although, the use is much profound in these domains, pneumatics and software engineering disciplines lack behind in being educated by VR.

Types of VR being used

The types of VR being used in the engineering education include head-mounted display (HMD) VR (most popular and widely used), desktop VR, mobile VR, and cave automatic virtual environment (CAVE) VR (Huang & Roscoe, 2020).

Applications of VR in various domains

VR is being employed in various engineering domains to enhance user learning and experience.

VR for Orientation and Mobility Training for Visually Impaired

A VR platform can simulate O&M training for persons with visual impairment and glaucoma, offering benefits like controlled environment, safe platform for learning new skills, and educating the public (Ricci et al., 2022). The platform can simulate obstacles, street crossing, and other common mobility difficulties for persons with VI, using the Universal Render Pipeline (URP) for high-fidelity simulation. Integration with Oculus headset and Touch controllers enables navigation and obstacle detection. This study is a preliminary step towards using VR in O&M training for persons with VI.

VRROS in Master's Module Teaching on Ships' Bridges

The Virtual Reality-Reconstructed Operation Scenarios (VRROS) can replace real fieldwork in teaching multimodal and distributed technology for ships' bridges (Frydenberg & Nordby, 2022). It offers advantages such as accessibility, speed, cost-effectiveness, time-saving, and easy revisiting. Students can produce prototypes based on VR recordings for exploring design possibilities. Although it cannot include ethnography, VRROS provides an effective alternative for teaching and learning ships' bridges technology.

VR Applications for Medical Education

VR applications can aid medical education during pandemics (Hsin et al., 2022). The study measured SSQ score, VLF power, and frustration in a 360° VR application for medical education. Simulator sickness management is important for improving VR training programs. VLF power can objectively monitor the occurrence and progression of SS. Combining HRV analysis with mental workload and SS measurements is recommended for evaluating VR applications in medical education.

Virtual Reality-Mediated Communication: A Complex and Promising Medium for Communication and Collaboration

A study on VR-mediated communication shows that it is as complex as face-to-face communication and can be used as an alternative to collaborative meetings and e-learning (Dzardanova et al., 2022). The study highlights the potential of VR in industries such as design, construction, engineering, and simulation. Future research directions include optimizing network latency, investigating participant task load, and exploring social psychology subtopics to inform the growing VR knowledge base.

The Potential of Virtual Reality Technology for Enhanced Training Outcomes in Education and Industry

Virtual Reality (VR) technology has the potential to improve training outcomes in both education and industry. In education, VR allows trainees to interact with building anatomy elements, while in industry, it can reduce training time and task errors (IV et al., 2021). However, rigorous evaluations are needed to fully understand the benefits of VR training, including standardizing technical terms and reporting results appropriately.

The VR Multisensory Classroom for Immersive Organic Chemistry Learning

The VR Multisensory Classroom (VRMC) is a learning system that employs natural hand motion (haptics) to build molecules in a VR environment for learning organic chemistry (Edwards et al., 2019). The system integrates immersive, multisensory, and tactile learning to promote engagement, motivation, and interest. The study shows positive user feedback on system usability and usefulness for learning. Future research could explore extending the learning content through different levels of gaming. The VRMC demonstrates how immersive VR technology can simulate abstract concepts and promote multisensory instruction for enhanced memory and engagement.

Ways VR is being used in Engineering Education

- Design and Prototyping: VR is used to create and test designs in a virtual environment, allowing engineers to visualize and optimize their designs before physical prototyping (Wang et al., 2021).

- Training: VR is used to train technicians on the installation, repair, and maintenance of engineering systems, allowing them to practice procedures in a safe and controlled virtual environment before working with real equipment.

- Simulation and Analysis: VR is used to simulate and analyze the performance of engineering systems under different conditions, identifying potential issues and optimizing performance before physical testing (Lanzo et al., 2020).

- Collaboration: VR is used for real-time collaboration among engineering teams, enabling them to interact with the virtual environment simultaneously, facilitating communication and improving productivity.

Format in which VR is being used

The class delivery format of VR can be divided into two categories (a) virtual and (b) traditional (Lanzo et al., 2020). VR in the virtual classroom format attempts to represent or replicate real-world engineering classroom environments in a three-dimensional (3D) virtual environment.

Motivation to use VR

The main motivations identified in the literature for the use of VR in engineering education are: (a) distance learning; (b) immersive learning and (c) recent development and integration (Lanzo et al., 2020). Most of the literature considers (b) and (c) to be the most important motivating factors whereas a few consider benefits of distant or remote learning methods, where virtual reality is used as a tool to provide distant or remote students with learning experiences they might not otherwise have, as a main motivating factor.

Learning Outcomes

The learning outcomes which VR achieves encompass three broad categories (Lanzo et al., 2020):

- Skill-based outcomes. This learning outcome focuses on the evaluation of performance in simulated and training environments and concerns the development of technical or motor skills. This is presented as an enhancement or improvement of students' academic graded performance.

- Cognitive outcomes. This learning outcome focuses on the evaluation of the dynamic processes of knowledge acquisition, organisation, and application. This is presented as an enhancement or improvement of students' knowledge retention and overall understanding.

- Affective outcomes. This learning outcome focuses on the evaluation of issues such as attitudes, motivations, and goals that are relevant to specified engineering learning goals. This is presented as an enhancement, improvement, or facilitation of students' development or acquisition of professional and personal skills ("soft" skills).

Evaluation Metrics

The main metrics being used in the literature for evaluation of the utility and overall perceived effectiveness of the use of a virtual reality system in engineering education environments (Lanzo et al., 2020) are as follows:

- Acceptibility and Validity: The level to which a system is tolerated, allowed, and logically or factually sound

- Usability and usefulness: The level to which a system is fit or able to be used, and whether it is perceived as actually useful

- Utility and effectiveness: The level to which a system is functional, beneficial, and successfully produces the desired result

Discussion

Virtual Classrooms

The reviewed literature indicates that virtual environments are useful for teaching complex industrial processes and creating controlled situations (Huang & Roscoe, 2020). The literature suggests that virtual classrooms can effectively assist students in retaining materials and improving educational outcomes, but further development is required to accurately and realistically represent simulated environments while being cost-effective.

Learning benefits

Virtual reality in engineering education has shown promising and beneficial results for skill-based and cognitive learning outcomes. However, widespread use is yet to be implemented due to cost issues. HMD virtual reality has shown the most favorable results but has issues such as cybersickness (Huang & Roscoe, 2020). Studies have shown that students who learned concepts in a virtual reality environment performed better than those who learned through traditional teaching methods. However, some studies have small sample sizes and lack formal evaluation, and cost-effectiveness is not always considered. It is important to ensure large sample sizes and rigorous evaluation to reinforce positive outcomes.

Evaluation Considerations

The evaluation of user experience in virtual reality environments lacks a robust evaluation model, resulting in variations across literature and making it challenging to assess the benefits of virtual reality in engineering education (Wang et al., 2021). Some studies incorporate feedback systems to better understand student content retention and satisfaction, but there is a lack of standardization and clear criteria for evaluation metrics. Establishing standardized evaluation criteria and processes would aid in future studies, allowing for easier comparison across literature.

Future Research

The use of virtual reality in engineering education can be confirmed by exploring its usage, user preferences, and best practices. Future research should develop valid evaluation models and comparable metrics to standardize evaluation processes (Lanzo et al., 2020). The realism of 3D virtual reality scenarios is important for improving the user experience, but hardware and software limitations may prevent the use of 3D scanning of real-world objects and situations.

Conclusion

The increasing popularity of virtual reality technology in education has positive effects on learning outcomes, but there is a lack of standardization in the evaluation processes and metrics. Defining major evaluation metrics, conducting formal evaluations, and balancing cognitive, skill-based, and affective learning outcomes are important for virtual reality to be effective in engineering education. In conclusion, virtual reality has the potential to revolutionize engineering education, but more research is needed to fully understand and optimize its benefits.

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