Virtual Reality in Civil Engineering Education

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Virtual reality (VR) learning tool was successful in enhancing students' understanding of the civil engineering experiment. The immersive and interactive nature of VR contributed to a solid grasp of the concepts presented, proving its potential as a valuable educational resource. By leveraging VR technology, educational institutions can provide an engaging and effective alternative to traditional laboratory sessions, ensuring uninterrupted and high-quality learning experiences for civil engineering students.

virtual reality | digital modelling | engineering graduates

1. Intro to VR

"Virtual Reality (VR) is an advanced, human-computer interface that simulates a realistic environment. The participants can move around in the virtual world. They can see it from different angles, reach into it, and reshape it" [1].

Since the 1950s, pioneering engineers and technology companies have both been inspired by renowned science fiction authors to turn this technology into tangible systems. One notable figure is Morton Leonard Heilig, a cinematographer who started developing the Sensorama (patented in 1962) [2]—an arcade-style theatre cabinet from the 1950s that simulated multiple senses using a stereoscopic 3D display; speakers; fans; smell generators; and a vibrating chair. Heilig also invented the Telesphere Mask, the first VR Head-Mounted Display (hereinafter called HMD) (patented in 1960) [3]. Another significant contributor is Ivan Sutherland, who, along with his students at Harvard University, created the "Ultimate Display", the HMD that rendered sequential images based on the viewer's movements, serving as the foundation for modern virtual reality technologies.

Since then, academic institutions and industry organizations like MIT, NASA, and Nintendo have made notable contributions to the underpinning technologies and user experience of head-mounted displays and conducted experimental trials in this field.

2. VR as a Method of Teaching

Bell and Fogler [4] state, "Many studies have shown that students learn best when a variety of teaching methods are used and that different students respond best to different methods". The research explores the potential of educational tools for chemical engineering. The authors find that the main strength is the "ability to visualize situations and concepts that could not be otherwise seen". In addition, student interest and enthusiasm are increased as a diversity of learning styles, including active, visual, inductive, and global, is possible. However, several weaknesses are present, such as the visual presentation of textual information like equations and definitions in the environment.

The research performed in [5] involved 39 students in the faculty of life sciences taking part in a VR dissection, which found that VR is much better than only using a textbook, but the actual dissection was best in real life, with VR being a good addition to it.

"Despite the cost of technical support, staff training, and space requirements caused by AR/VR, the need for physical space can be reduced, and areas may be redirected for other purposes". "All of this shows a positive impact on universities, including economic repercussions" [6].

Freina and Ott [7] found that 27% of Immersive VR Education-related papers are in the engineering topic, while 60% of papers are in the computer science topic, which shows there is already some development with the potential for growth in the area. The journal concludes by saying, "Immersive VR can offer great advantages for learning: it allows a direct feeling of objects and events; it supports training in a safe environment, avoiding potential real dangers; and, thanks to the game approach, it increases the learner's involvement and motivation while widening the range of learning styles supported".

3. VR in Civil Engineering Education

There have been several applications of virtual reality technology being incorporated in the area of civil engineering instruction. The research on this is generally supportive of VR as a means of instruction [8][9], particularly to replace dangerous or expensive laboratory trials [10] or as a means of increasing situational awareness of engineering environments [11][12].

Early work in this area was carried out by Sampaio et al. in [13], where students were shown a virtual simulation of a bridge under construction to improve their understanding of the concepts involved. The authors indicated that students' understanding increased, but no quantitative data were included to support this. The technology at the time did not allow for very realistic simulations, as the engines used to develop the software were not powerful enough at this time. Further work was conducted by Dinis et al. in [14], where K-12 students were presented with a simple VR application that highlighted areas related to specific disciplines of engineering (structural, construction, hydraulics, etc.) to aid student understanding of basic civil engineering concepts and how they apply to the world around them. The authors used a Likert scale to measure engagement but did not investigate improvement in relation to learning outcomes. This gap between simulation development and learning outcomes was also raised by Liang in [15], as the author raised the concern that there are not close enough links between developers of software and the academic community that will be implementing them.

With the release of more powerful tools for developing VR experiences, photorealistic simulations could be integrated into courses. The high-resolution recreation of a construction site in [16] allowed for increased immersion due to the detailed graphics present in the simulation. The qualitative data indicated that the students enjoyed the experience, but the inability to interact directly with elements of the experience reduced the effectiveness of the simulation as a teaching tool. To address this concern, the digital learning environment presented in the research was developed using a game engine. The functionality available from their original use as an engine for developing games and interactive experiences meant it could be applied to this project, as was also carried out in [17].

A study [18] aimed to determine if VR can be successfully implemented as a practical exercise replacement while allowing students to develop their skills without physically completing a practical exercise as well as supporting students within laboratory-based exercises. During the research, the learning tool was designed to replicate the reaction of a concrete beam during point loading. During the exercise, the user was able to see the failure of the beam as a result of the applied load, just as it would fail in reality. Following the exercise, the users completed a questionnaire to evaluate their perceptions of their experience with the program and to evaluate their understanding through a series of technical questions. Overall, the questionnaire showed positive interaction with the program, and based on the technical questions, it proved to provide the students with enough knowledge to enforce a clear understanding of the experiment. In addition, when comparing the results with the video-recorded lab, the VR workshop has proven to be more beneficial to the students' understanding and engagement with the exercise compared with the video-recorded lab. Furthermore, there was only a minor difference in results when comparing the VR workshop with the physical in-person lab, which proves that VR can successfully be implemented as an alternative to traditional laboratory teaching.

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