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Exploration of Teaching Practice of Engineering Mechanics Course in Municipal Engineering Technology Major under Artificial Intelligence

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Abstract

This paper explores the integration of Artificial Intelligence (AI) and Virtual Reality (VR) technologies in the teaching of Engineering Mechanics (EM) within the municipal engineering technology major. EM is a fundamental course that equips students with the core principles necessary to analyze and solve real-world engineering problems related to the design, construction, and maintenance of infrastructure. Traditional teaching methods, such as lectures and textbook exercises, often fail to fully engage students or provide adequate hands-on experience with complex mechanical phenomena. The application of AI and VR technologies offers a promising solution to enhance learning outcomes by providing interactive, immersive, and personalized educational experiences. In this study, we propose the development of an AI-driven VR-based teaching platform for EM that combines personalized learning paths with highly immersive simulations. AI is employed to tailor learning experiences based on individual student progress and performance, while VR is used to visualize and simulate real-world mechanical systems, enabling students to interact with complex engineering scenarios in a controlled virtual environment.

Keywords: engineering mechanics, quality and connotation, engineering mechanics Education, virtual reality (VR) technology

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1 Introduction

The teaching of Engineering Mechanics (EM) is crucial for students pursuing degrees in fields like municipal engineering, civil engineering, mechanical engineering, and related disciplines. Engineering Mechanics is foundational for understanding how forces interact with physical systems, a knowledge set that is essential for designing and evaluating infrastructure, machinery, and various structures that constitute the modern built environment. EM encompasses core principles from statics, dynamics, strength of materials, fluid mechanics, and solid mechanics, which collectively form the basis for understanding the behavior of materials and structures under different conditions [1–3].

In the municipal engineering technology major, *Engineering Mechanics* covers a wide range of topics that are directly applicable to real-world engineering problems. The main areas of study include the analysis of forces and moments, the deformation of materials, structural stability, and the behavior of fluids within systems like pipelines or water distribution networks. The primary focus of the course is to build students' ability to predict the responses of materials and structures to applied forces, which is a key skill in the design, construction, and maintenance of infrastructure. However, due to the inherent complexity of these topics, students often struggle to fully grasp abstract mechanical concepts, particularly when trying to apply them to real-world scenarios [4–6].

Traditional methods of teaching EM rely heavily on theoretical lectures, textbook examples, and static problem-solving exercises, which, while important, can fail to fully engage students or provide sufficient hands-on experience. For example, in statics, students must analyze forces acting on stationary bodies, and in dynamics, they need to understand the motion of objects under the influence of forces. These are abstract concepts that are difficult to visualize, especially when students must consider multi-dimensional scenarios or non-intuitive phenomena like stress distribution in materials. The limitations of traditional teaching methods make it difficult to provide the immersive, interactive learning experiences that are essential for deep understanding, particularly in fields where practical application is key [7, 8].

The application of *Engineering Mechanics* to municipal engineering involves the study of how mechanical principles can be applied to real-world challenges such as structural design, material selection, transportation systems, and urban infrastructure. In this context, students need to understand how forces affect not only individual components but also entire systems, such as the design of bridges, tunnels, road networks, water supply systems, and sewage infrastructure. For instance, the design of a bridge requires an understanding of statics (how forces and moments act on the bridge structure), material mechanics (how the materials respond to these forces), and dynamics (how the bridge will behave under moving loads). Similarly, understanding fluid mechanics is vital for designing efficient water treatment plants and drainage systems. To succeed in these tasks, students must be able to model and analyze complex mechanical systems, something that is difficult to achieve with conventional teaching methods alone [9, 10].

To address these challenges, new teaching methods incorporating *Artificial Intelligence* (AI) and *Virtual Reality* (VR) technologies have the potential to provide a more immersive, interactive, and personalized learning experience. AI can enable personalized learning experiences by adapting the content to meet each student's needs, while VR can simulate real-world scenarios, allowing students to visualize and interact with complex mechanical systems in ways that traditional textbooks and lectures cannot achieve.

By incorporating AI and VR, students can experience more hands-on learning through interactive simulations that reflect real-world applications of *Engineering Mechanics* principles. For example, a student might simulate the behavior of a structure under different loading conditions, or they might visualize the deformation of materials in real-time under stress. These types of immersive experiences not only help students better understand theoretical concepts but also provide them with a deeper understanding of how these concepts are applied in real engineering practice. This approach has the potential to bridge the gap between theory and practice, allowing students to engage in practical problem-solving and gain experience in a safe, controlled environment.

The integration of AI and VR in the teaching of *Engineering Mechanics* can revolutionize the way students learn about engineering concepts, offering the possibility of personalized, interactive, and highly immersive education. In municipal engineering technology programs, this approach is especially valuable because it allows students to understand and apply mechanical principles in the context of large-scale infrastructure projects. The ability to simulate real-world engineering scenarios in a virtual environment allows for the exploration of complex systems, where students can observe and analyze behaviors that would be difficult or impossible to replicate in a traditional classroom or laboratory [11].

For instance, the use of VR simulations in the analysis of stress distribution in materials or the behavior of structures under dynamic loading can help students visualize concepts that are otherwise abstract. By interacting with these simulations, students can gain a more intuitive understanding of mechanical principles and their real-world applications. Additionally, AI-driven platforms can track students' progress and provide real-time feedback, enabling them to focus on areas where they need improvement and offering personalized learning paths.

Furthermore, there is a need for careful consideration of the educational value of AI and VR-based tools. While these technologies have the potential to enhance learning, it is crucial that they are used in a pedagogically sound manner. The integration of AI and VR should not simply be for the sake of novelty but should be designed to address specific learning objectives and enhance students' understanding of *Engineering Mechanics*.

2 Related Work

The concept of VR was first proposed by Jaron Lanier (USA) in 1987 [11]. Burdea G and Philippe Coiffet proposed the basic characteristics of VR [12, 13], which are usually used to represent the characteristics of VR technology with three "I's", as shown in Figure 1.

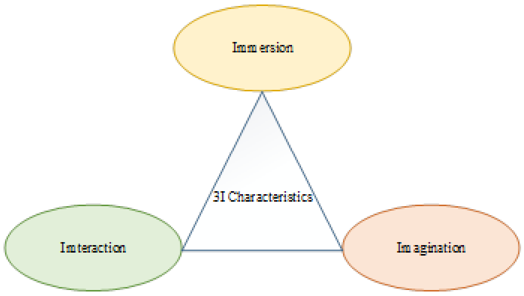

Figure 1. Characteristics of VR

VR technology was first developed in the United States, where Ivan Sutherland first proposed the theory of VR in his PhD thesis in 1963 [14]. It was only in 1989 that Yaron Lanier, the founder of VPL Research, introduced the term VR to the general public [15]. After more than 50 years of development, the United States is still a world leader in the development of VR technology. Its application has become more and more widespread and has entered all aspects of the life of the masses from the defense field created by major universities or research institutes. For example, Oculus Rift DK2, a head-mounted VR display device, provides gamers with an immersive gaming experience; Gear VR, a VR device developed by Samsung in 2014, can watch VR movies and videos with the help of a smartphone, the VR amusement park created by The Void Company in Utah in 2016 has officially opened to the public.

As can be seen from the above, the research process of VR technology in some developed countries in the West is very fast and its attention is high. From the early use of VR technology in national defense, military, etc., it has now been widely developed into specific subject teaching such as medicine, chemistry experiments and distance education. This shows that the future application of VR in the subject education curriculum has great potential for development.

3 Methods

In this paper, we focus on how to establish a engineering mechanics teaching platform with the help of VR technology to assist in improving the quality and connotation of college students, and firstly, we compare the advantages and disadvantages of the existing VR teaching application modes.

3.1 Platform design ideas

Based on the rich network cultural resources, the engineering mechanics Education Cloud Platform takes the promotion of network quality and connotation of spirit as the forerunner. The engineering mechanics Education Cloud Platform takes historical events as the core material, uses cloud computing and real-time rendering engine and other technical support, and combines a variety of hardware terminals to provide users with high-quality services, as shown in Figure 2.

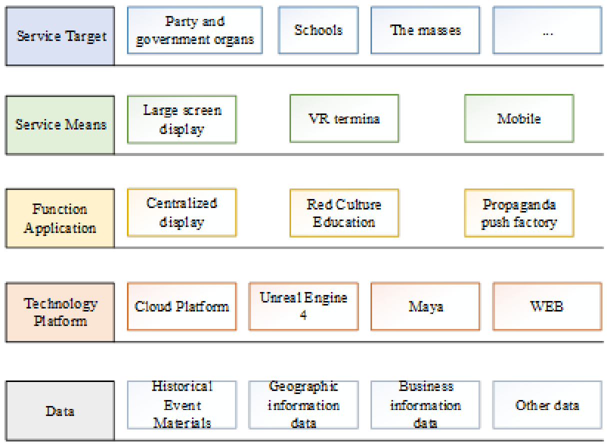

Figure 2. The overall architecture of the platform

3.2 Platform architecture design and application planning

The cloud-based system architecture has better support for massive data storage and management, concurrent task rendering, complex scene rendering, etc. As shown in Figure 3, to improve the flexibility of the engineering mechanics Education Cloud Platform and reduce the performance requirements of the platform for application terminals, the platform will adopt the application mode of deploying multiple ends for use in the cloud.

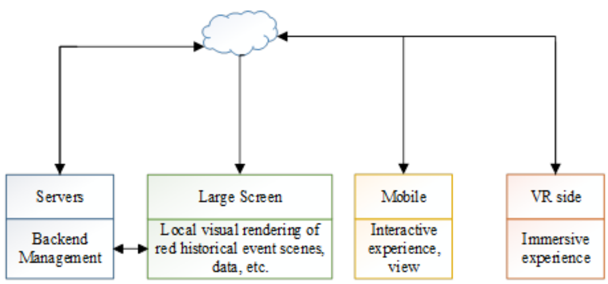

Figure 3. System application model

3.2.1 *Cloud deployment*

The platform contains data resources of several network quality and cultured old sites, which can

VR teaching application model	Graphical	Advantages	Disadvantages
Mobile VR and VR all-in-one application mode		Can meet in ordinary classrooms or laboratories at the same time to make more people, easy to carry, VR all-in-one machine immersion and interactivity is strong	Mobile VR devices have lower technical content and less experience and interactivity
Host VR application mode		Best immersion and interactivity, students can get the best individual experience	More expensive, higher equipment and space requirements, poor portability
Host VR+ Large screen application mode		Suitable for large classes, solving the problem of multiple people visiting the experience at the same time	Students do not enter the VR scene in the senses, immersion is not strong, the experience is weak
VR stereoscopic projection application mode		Strong sense of presence and immersion	The number of audiences at the same time and place is limited, and it is more difficult to invest in equipment and content development

Table 1. VR teaching application mode comparison table

be subsequently extended to cover more than forty network quality and cultured old sites. It is stored in the cloud server using the cloud deployment. Tasks such as resource data downloading, scene rendering and video stream distribution can be completed according to user usage to meet different application scenarios.

3.2.2 Large screen display

The large screen display system has the characteristics of high resolution, fine picture quality and single application mode, which requires high rendering ability of computer and is generally deployed in fixed places such as exhibition halls. This mode will adopt local deployment of high-performance servers and download data resources from the cloud to local rendering for visualization of engineering mechanics Education scenes to achieve shocking visual effects.

3.2.3 VR Experience

According to the application mode, VR glasses are mainly divided into three categories, namely: cell phone boxes, head-mounted displays and VR all-in-one machines. The cell phone box is used as a rendering terminal for VR rendering through the cell phone as a virtual scene, and its rendering capability and display accuracy are limited by the performance of the cell phone hardware. The head-mounted display itself only serves as a display terminal and requires an external computer for image computation and rendering. the VR all-in-one machine has a built-in display, gyroscope, computation and other modules with strong computing power and is easy to carry and deploy. Therefore, the engineering mechanics Education Cloud Platform uses the VR all-in-one machine as an immersive experience terminal.

The VR machine is connected to the platform through the Internet for downloading and updating resources, and the user selects different scenes for touring experience through the interactive handle. the VR machine renders parallax left- and right-eye images in real time according to the direction of the field of view and projects them onto the screen of the VR machine to build a highly immersive 3D image , as shown in Figure 4.

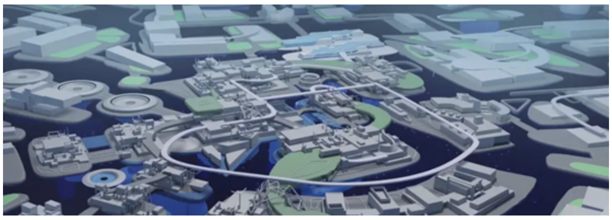

Figure 4. VR experience effect map

3.2.4 Mobile end experience

The mobile terminal is mainly used as a temporary experience terminal. Users log in through the platform interface, select the scene they need to experience and then have the scene rendered by the cloud and transmitted to the mobile terminal for presentation by means of video streaming. The experience device itself does not require resource downloading and rendering calculation, which greatly reduces the dependence on hardware performance.

3.3 Key Technologies

3.3.1 Large terrain simulation technology

The real-time degree of the scene in the virtual environment, the visualization range of the scene, and the details of the scene have a direct impact on the visualization effect of the final presentation. At present, the main way to produce large landscapes is to use Digital Elevation Model (DEM) to generate a base model with height information and Digital Orthophoto Map (DOM) mapping to build a large scale geographic environment. To achieve a better experience effect, the engineering mechanics Education Cloud Platform generates terrain scenes according to the real geographic data information of the old red sites, and based on the traditional DEM+DOM technology method, the vegetation system provided by Unreal Engine 4 (UE4) is used to generate more realistic ground cover according to the ground texture information, which makes the scene effect more realistic and delicate. The specific effect is shown in Figure 5.

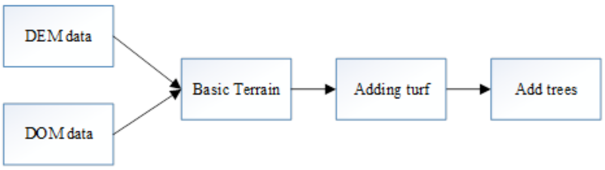

Figure 5. Large terrain simulation

3.3.2 High-precision modeling techniques

To achieve a good picture effect, it is necessary to restore the old red sites and historical events with high precision. However, the screen presentation of the engineering mechanics Education Cloud Platform is based on real-time rendering by the UE4 engine, and the larger the amount of model data is, the more serious the consumption of system resources is, and the lower the system operation efficiency is. In order to get a good experience, the system refresh rate should generally be greater than 30Hz for non-immersive experience and 60Hz for immersive experience. Deep optimization of virtual scene resources is required to meet the functional and rendering quality requirements in order to reduce the load pressure on the platform hardware. Next-generation modeling technology uses normal baking to retain the details of high-precision models in the form of mapping, and the mapping is given to low-mode to obtain the same appearance as high-precision models. The next-generation modeling method can obtain good visual effects and does not waste system resources due to the excessive number of model faces.

3.4 Platform implementation

3.4.1 Technical route

The engineering mechanics Education Cloud Platform is developed by combining VR technology with engineering mechanics Education resources. Firstly, the material is collected and organized, such as photos, videos and text materials. Next, according to the materials, Maya modeling software is used to refine the modeling and animation of key scenes and characters, and the surrounding terrain is restored based on real geographic information data. UE4 engine is adopted as the key platform for visualization of virtual scenes of engineering mechanics Education, and the human-computer interaction interface and interaction logic are constructed using blueprint programming. Cloud storage and deployment are used to provide services such as resource download and online rendering for multiple types of end users.

3.4.2 Functional design and implementation

1. Scene visualization

   The system uses UE4 as the virtual scene visualization engine, which can obtain realistic and real-time rendering effects. The engine supports real-time rendering of different weather environments, road environments, natural light, ambient light and reflections. UE4 takes into account the balance between system operation efficiency and rendering quality, providing powerful light sources, materials, shadows and reflections to handle the visualization of complex scenes with high quality and speed. The environment, lighting and materials can be changed in real time, and it has the ability to render the environment, lighting and materials in real time and realistically. UE4's excellent real-time rendering ability provides a strong guarantee for visualization of engineering mechanics Education scenes.

   In the process of developing the Engineering Mechanics Education Cloud Platform, scene design plays a critical role in creating an engaging and immersive learning environment for students. To enhance the educational experience, virtual scenes are designed to simulate real-world engineering scenarios. Using advanced software tools, elements such as textures, materials, and lighting are meticulously crafted to ensure accuracy and visual appeal. These realistic scenes help students better understand complex engineering mechanics concepts by providing a vivid, interactive context for exploration. The scene design and its effects are illustrated in Figure 6.

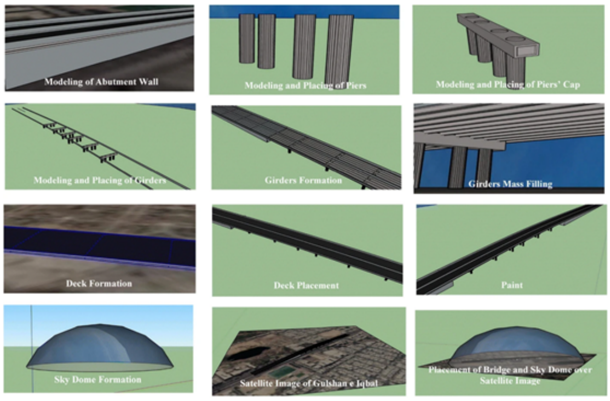

Figure 6. Revolutionary virtual scene restoration

2. Sound Simulation Design

The accuracy of information processing in the brain can be improved with the correlation of auditory and visual effects, and the overload of a single information channel can be avoided. VR is not only a visual simulation, but also a three-dimensional simulation of various types of sounds in the scene is particularly important. The main sounds in this training system include.

1. Background sound

The scene environment is analyzed to sort out the main background sound types, locations and approximate volume. By setting the pronunciation virtual body at the corresponding position in the virtual environment and setting a certain random change value for simulation, a more realistic effect is achieved.

2. Event sound Historical event virtualization restoration mainly involves the sound of guns, explosions, punch lines, character dialogues, narration introduction, etc. Through the program control, according to the virtual scene events, interactive instructions trigger the corresponding sound content, to achieve the integration of audio-visual display effect.

3. 3D menu design

In the immersive experience environment, in order to quickly and conveniently perform operations and function selection, the platform provides visitors with a 3D menu, and the corresponding operations are performed after calling out the menu through the preset buttons of the VR handle, as shown in Figure 7.

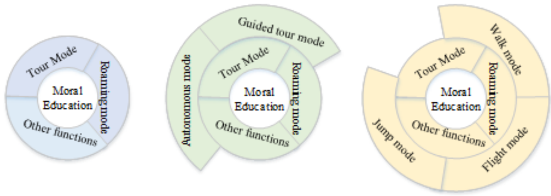

Figure 7. 3D menu design

4. Virtual roaming Visitors can roam at will in the virtual scenes of the old red sites selected in the engineering mechanics Education line to browse the images, texts and statues in the old sites.

5. Interaction design

The main purpose of design is how to make users better interact with the system. Human-computer interaction design should focus on system ease of use, process simplicity, blind spot testing, error and exception prompting, user environment testing, etc. The engineering mechanics Education System uses UE4's unique blueprint programming for HCI design and development. The visualization scripting class is well suited for creating interactive resources, such as opening and closing doors, object picking, animation triggering, sound triggering, material transformation, etc. It can respond according to user's operation, location and voice recognition to achieve autonomous, automated and intelligent human-computer interaction effects.

6. Plot design In the display process, a space-oriented, storytelling approach is employed to create a sequence of events with rhythmic configurations such as opening and closing, hurrying and loosening. This design enables users to better immerse themselves in the spatial environment. The Engineering Mechanics Education System uses real-world engineering projects, such as roads, bridges, and pipeline networks, as prototypes. Through artistic design techniques, it introduces project backgrounds with voice explanations, presents engineering processes with interactive 3D animations, and demonstrates final outcomes with detailed graphic materials. This approach constructs a comprehensive interpretation of engineering practices and forms a cohesive narrative aligned with real-world scenarios. By allowing users to

engage in the entire process from a first-person perspective, the system provides a highly realistic, impactful, and engaging learning experience, fostering a deeper understanding of engineering mechanics principles and their practical applications.

7. Navigation and interpretation

The virtual robot provides voice guidance or projects video displays based on the user's location during the tour, as shown in Figure 8. This navigation method combines modern technology with real-world engineering examples, such as road construction, bridge design, and pipeline network installation, to create a more interactive and engaging system. By simulating engineering processes and highlighting key technical details, the system enhances the learning experience, allowing users to explore complex engineering mechanics concepts in an intuitive and immersive manner.

Figure 8. Navigation tips

4 Case Study

Through visiting and experiencing the virtual learning platform, students can gain a deeper understanding of the design, construction, and operation of real-world engineering projects such as roads, bridges, and pipeline networks. This approach not only showcases the rapid development and application of modern information technology but also fosters a spirit of innovation, patriotism, and dedication to national infrastructure development.

The most significant feature of the VR learning platform is its ability to create immersive environments that replicate real engineering sites. This allows students who are unable to visit such locations in person due to logistical constraints to overcome barriers of time and space. By engaging with the VR platform, students can explore complex engineering scenarios, interact with virtual models in real-time, and enhance their understanding of engineering mechanics concepts, thereby promoting equitable access to high-quality education.

Learning in these VR-based scenarios transforms traditional classroom teaching into an engaging, limitless experience. Students can explore virtual sites, analyze engineering structures, and develop hands-on skills, making them more confident in their understanding of both advanced technology and the practical applications of engineering mechanics in China.

To evaluate the effectiveness of this platform, a questionnaire was designed with single-choice, multiple-choice, and open-ended questions, totaling eleven items. These were distributed to students who participated in a university course focusing on educational technology. The results revealed that while some students were unfamiliar with VR technology, the majority had prior knowledge or were eager to learn about its applications. This indicates a strong interest in the integration of immersive VR technology into education. The statistical findings are presented in Figure 9.

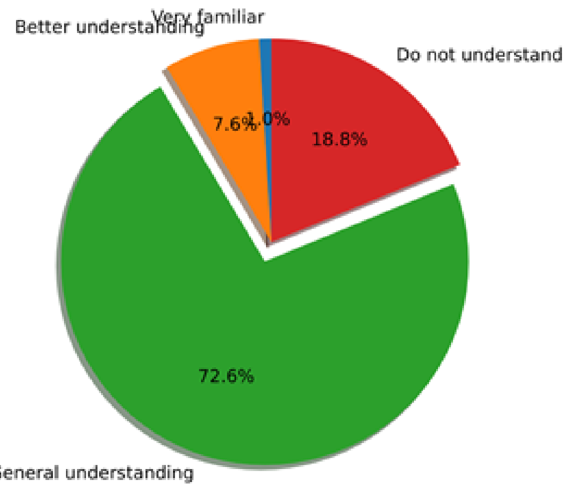

Figure 9. The survey on whether they know about immersive VR technology

Before engaging with the VR platform, only 54% of the students had prior experience with VR technology, and most of them found it to be a highly realistic and immersive tool. However, 46% of the students had not previously interacted with VR, highlighting the need for broader dissemination and adoption of this technology in educational contexts.

The VR platform, featuring real-world engineering scenarios such as road construction, bridge design, and pipeline network installation, provides an excellent opportunity to familiarize students with immersive technology. By enabling hands-on experiences in virtual environments, it bridges the gap between theoretical learning and practical application, making engineering concepts more tangible and engaging.

The survey results, as illustrated in Figure 10, emphasize the importance of popularizing VR technology to ensure that more students can benefit from its innovative educational potential and understand its significant value in fields like engineering mechanics.

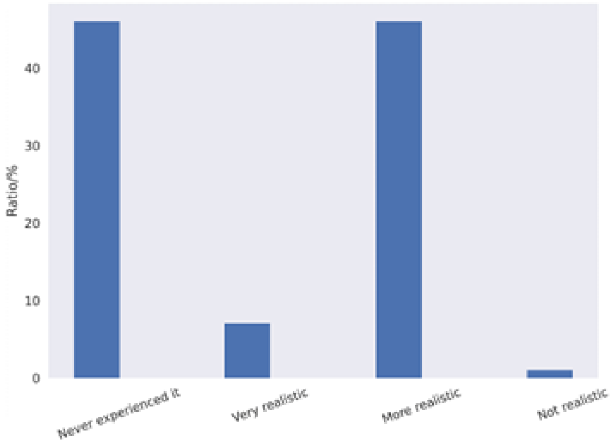

Figure 10. The survey on whether you have experienced immersive VR technology before this

Students expressed overall satisfaction with the engineering mechanics practice course conducted through the VR teaching platform, which featured real-world scenarios such as road construction, bridge design, and pipeline network engineering. According to the survey, 38% of the students were "very satisfied," while 58% were "satisfied." These results, as shown in Figure 11, demonstrate a strong preference among students for this innovative teaching approach.

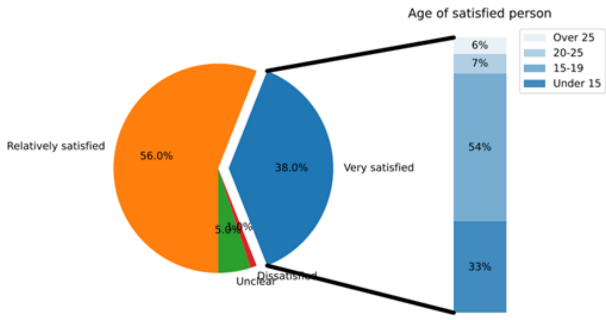

Figure 11. The results of survey on whether satisfied with the practical teaching of engineering mechanicss class based on VR teaching platform

The VR-based classroom enabled students to engage more deeply with practical engineering concepts by immersing them in realistic and interactive environments. This method not only enhanced their understanding of complex topics but also fostered greater enthusiasm for learning. The high satisfaction rates indicate the potential of VR technology to transform traditional teaching methods and improve the overall quality of education in engineering mechanics.

More than 80% of the students reported experiencing the immersive and interactive qualities of VR technology during their learning sessions on the platform, which featured engineering scenarios such as road construction, bridge design, and pipeline network systems. Immersion and interactivity were identified as the two primary strengths of the virtual classroom. However, over 40% of students noted that these features were not as pronounced in some parts of the platform, indicating room for improvement in delivering a more consistent VR experience.

Students highlighted the unique capability of VR technology to create realistic scenarios that mirror real-world engineering challenges or even imagine environments that do not exist in reality. This capability allows learners to explore and experiment freely in a virtual world, enhancing creativity and understanding.

The questionnaire results, as illustrated in Figure 12, underscore the potential of VR platforms to revolutionize engineering education by offering highly engaging, interactive, and imaginative learning environments. Addressing the noted limitations could further optimize the educational impact of VR-based learning.

The VR teaching platform provides an effective foundation for practical teaching in both engineering mechanics and interdisciplinary subjects. It offers immersive and experiential learning environments tailored to real-world scenarios such as road construction, bridge design, and pipeline network systems. According to the survey, 35% of students reported that the contextual and hands-on teaching methods available on the platform significantly helped them address challenges in their learning. Additionally, 65% of students stated they were "very willing" to continue learning with this VR-based approach, 30% chose "willing," and only 3% expressed a neutral stance. Importantly, no students indicated they were "unwilling," demonstrating strong enthusiasm for the VR teaching model.

Compared with traditional teaching methods, 96% of

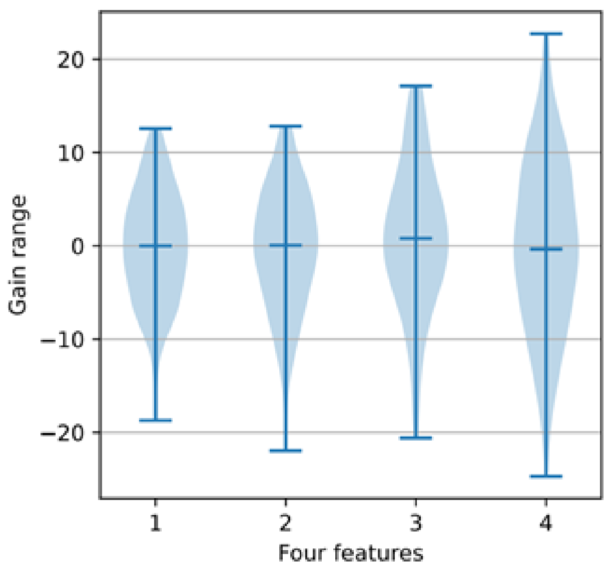

Figure 12. The survey on what features you think the VR teaching platform has

students preferred the innovative VR-based learning experience, which they felt offered a more engaging and impactful classroom environment. While more than 65% of students found the introduction of immersive VR technology highly feasible, 35% expressed reservations, reflecting the natural skepticism often associated with new technologies during their early adoption stages. Nevertheless, the overwhelmingly positive response indicates that VR teaching holds significant promise for enhancing education.

Nearly 90% of students showed optimism about the future application of VR technology in education, with 23% being "very optimistic" and only 11% expressing limited optimism. These findings underscore the broad acceptance and potential of VR technology to transform traditional teaching methods.

However, the study also identified areas for improvement. Limited availability of VR equipment occasionally led to uneven access, with some students experiencing longer or shorter usage times. Enthusiastic early users often prolonged their sessions, reducing access for others. These logistical challenges highlight the need for optimized scheduling and increased resource allocation.

A comparison of student performance before and after the application of the VR teaching model, as shown in Figure 13, reveals significant improvement. This data reinforces the educational value of VR technology, showcasing its ability to enhance student comprehension and engagement in complex engineering concepts.

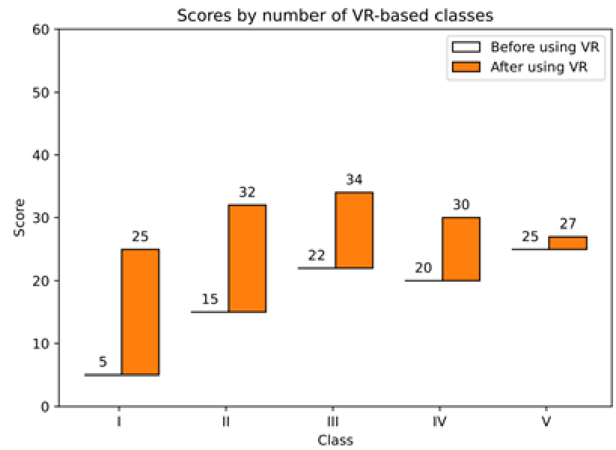

Figure 13. Student course score growth before and after the application of VR

5 Conclusion

This study demonstrates the effective integration of AI and VR technologies in teaching Engineering Mechanics (EM) within municipal engineering education. The proposed AI-driven VR platform enhances student engagement, providing immersive, interactive learning experiences that bridge theoretical knowledge with practical application. Over 80% of students reported improved understanding, with a majority expressing strong interest in continued use of the platform. The study highlights the platform's potential to revolutionize engineering education by offering personalized learning paths and realistic simulations.

Future studies should explore expanding the platform to other engineering disciplines, optimizing hardware for broader accessibility, conducting long-term evaluations of its impact, enhancing interactivity through haptic feedback, and developing standardized assessment frameworks to measure effectiveness.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

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