VIRTUAL COLLABORATION IN THE CONTEXT OF TEACHING AND LEARNING WITH INTERDISCIPLINARY PERSPECTIVE

Jiangfan Feng , Yanjie Gong, and Mao Tian

School of Computer Science and Technology, Chongqing University of Posts and Telecommunications, Chongqing 400065, China

ABSTRACT

Online virtual environments where students can learn and interact somewhat realistically have great potential for engineering studies, such as course resources, tools, and software that support learning and educational practice. Here, we present a collaborative virtual environment for interactive learning and immersive visualization with an interdisciplinary perspective. It allows users to visualize and sample complex scenarios' structures and dynamics and interact with other users in the same virtual environment. A series of controlled studies have been made in which participants were tasked with various emergency decision goals. Moreover, it can also support the following integrated functions: 3-D spatial analysis, 3-D visualization for spatial process, and 3-D spatial decision-making. The performance evaluation results confirmed the proposed virtual environment's higher usability and user satisfaction. This approach will be able to express opportunities for extending interdisciplinary knowledge in engineering education and support the students in their creativity and collaboration skills.

KEYWORDS

Engineering Education, Virtual Collaboration, Interdisciplinary, Virtual Learning

1. INTRODUCTION

Project-based learning (PBL) has gained recognition in recent years as a powerful approach to fostering critical thinking and promoting active learning in higher education (Iserte et al. 2023). This methodology allows students to engage in real-world problems, encouraging them to think critically, collaborate, and develop the skills necessary for success in their chosen fields. Implementing project-based learning has become increasingly relevant in engineering departments, where the need to improve undergraduate education and address high attrition, dropout, withdrawal, and failure rates is particularly pressing (Kuo et al. 2019).

Traditionally, engineering education has been characterized by its emphasis on theoretical concepts and reliance on lectures, textbooks, and exams (Baligar et al. 2022). However, it is well-understood that more than this approach is needed in preparing students for the complexities of real-world engineering challenges. Engaging engineering students in the learning process and providing them with realistic and interactive experiences has always been a challenge. Fortunately, technological advancements have given rise to online virtual environments, which have emerged as a promising solution for transforming education in engineering and other domains. Virtual environments present abundant opportunities to enhance the learning experience and equip students with the necessary skills to overcome the challenges they may encounter in their professional endeavors. By integrating project-based learning into these virtual

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environments, students can engage with complex scenarios, visualize structures and dynamics, and interact with their peers in an immersive and interactive manner.

In this article, we present a collaborative virtual environment specifically designed to enhance engineering education. This innovative platform is a hub for interactive learning and immersive visualization, providing students access to course resources, tools, and immersive experiences. Through this environment, students can engage with real-world engineering challenges, simulate and explore complex scenarios, and observe the structures and dynamics of various systems.

One of the key features of the collaborative virtual environment is its ability to allow users to visualize and sample the structures and dynamics of complex scenarios. By simulating these scenarios within a virtual environment, students can better understand the underlying concepts and their practical applications (Manusarpong et al. 2013). Whether it involves analyzing fluid dynamics, studying the behavior of complex systems, or visualizing the spatial arrangements within large-scale structures, this platform provides students with the tools and resources to explore these concepts intuitively and interactively. Moreover, the collaborative virtual environment fosters interdisciplinary perspectives by enabling students from different engineering disciplines to collaborate and work together (Zhi et al. 2018). The multidisciplinary approach plays a critical role in equipping students with the necessary skills for their future professional careers, as engineering projects frequently demand collaboration across diverse domains. By working together in a virtual space, students can develop a deep understanding of engineering concepts while honing essential skills such as creativity, problem-solving, and collaboration. In addition to its interactive and collaborative features, the collaborative virtual environment supports a wide range of integrated functions. These functions include tools for data analysis, simulation, and visualization, as well as features for communication and collaboration. With these integrated functions, students can engage with the course material and interact with other users, solve problems, and develop innovative solutions.

Overall, the collaborative virtual environment we present in this article offers a unique and practical approach to enhancing engineering education. By combining project-based learning, immersive visualization, and interdisciplinary collaboration, this platform provides students with a comprehensive learning experience that prepares them for the challenges and opportunities in their engineering careers. Students can develop a deep understanding of engineering concepts and foster essential skills such as creativity and collaboration by engaging with complex scenarios, visualizing structures and dynamics, and interacting with their peers. Through this innovative platform, we aim to revolutionize engineering education and empower students to become successful and impactful engineers.

The paper is organized into five sections. Section 2 outlines the methodology used in the study. In Section 3, the evaluation and results of the proposed method are presented. Section 4 delves into the principles and relationships discussed. Finally, Section 5 offers a summary of the work conducted.

2. METHODOLOGY

As shown in Figure 1, we aim to apply technologies such as virtual reality, multimedia, human-computer interaction, databases, network communication, and artificial intelligence to address issues related to the construction, integration, openness, and sharing resources in spatial information. It aims to go beyond the existing experimental teaching framework centered around sharing spatiotemporal data and move towards a knowledge-sharing platform centered around databases and model libraries. The focus shifts from observation and summarization of the natural geographical world toward comprehensive information mining and simulation reasoning, creating a new environment for knowledge generation.

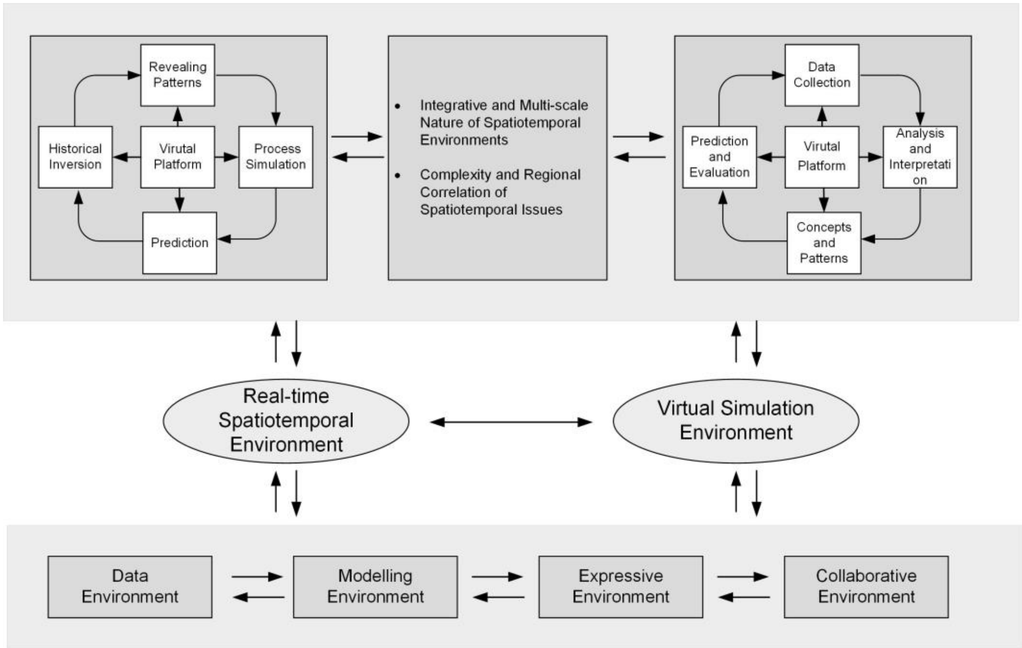

Figure 1. Overall Framework

2.1. Enhancing Learning Through Immersive Visualization

Immersive visualization is pivotal in enriching the learning experience within the collaborative virtual environment. By simulating complex scenarios and their structures and dynamics, students are provided with a virtual space to visualize and explore various engineering challenges. This chapter explores the different methods and techniques used to enhance learning through immersive visualization.

One of the standout features of the virtual environment is its support for 3-D spatial analysis. This functionality allows students to analyze spatial data and gain insights into engineering contexts' underlying patterns and relationships. By manipulating and interacting with the visualized information, students can deepen their understanding of spatial processes and make informed decisions. For example, in civil engineering, students can analyze traffic flow in a 3D environment to better understand the impact of design choices on traffic patterns (see Figure 2).
Moreover, the virtual environment enables 3-D visualization of spatial processes. By representing engineering concepts in a three-dimensional space, students can grasp the intricacies of these processes more effectively. Whether it involves visualizing fluid dynamics or understanding the spatial arrangements within large-scale structures, this feature empowers students to observe and comprehend complex phenomena intuitively. For example, mechanical engineering students can explore a machine's internal workings by virtually dismantling and inspecting its components in a 3D environment.

To further enhance the learning experience, immersive visualization techniques can be combined with interactive simulations (Dunston et al. 2011). These simulations allow students to actively participate in learning by manipulating variables and observing the resulting changes in real time. For example, in an electrical engineering course, students can interact with a virtual circuit, adjust the parameters, and observe how different values affect the overall performance.

In addition to interactive simulations, gamification elements can be incorporated into the immersive visualization environment to increase engagement and motivation. By adding challenges, rewards, and levels, students are incentivized to explore and interact with the virtual environment in a more active and enjoyable way (De et al. 2022). This gamified approach can be particularly effective in teaching complex engineering concepts that may otherwise seem daunting or abstract.

By leveraging immersive visualization techniques, educators can create a dynamic and immersive learning environment that promotes active engagement and deep understanding of engineering concepts. The visual representation of concepts and processes aids students in comprehending and internalizing the theoretical aspects of engineering, while interactive simulations and gamification elements enhance the practical application of knowledge. Through these methods, students are provided with a powerful tool for exploring, experimenting, and collaborating in the field of engineering.

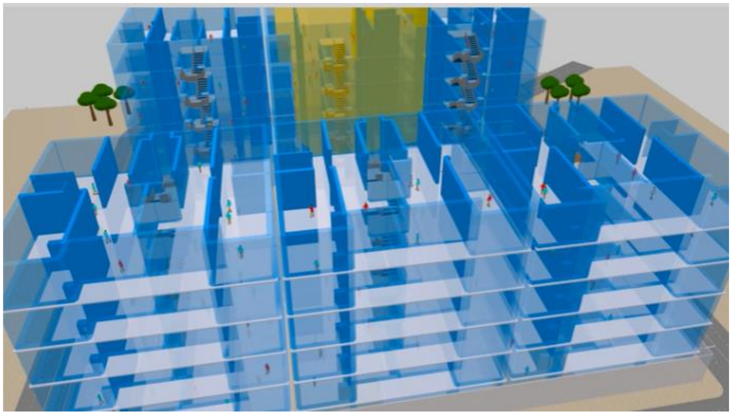

Figure 2. Screen captures from the virtual project.

2.2. Promoting Collaboration and Interdisciplinary Learning

Collaboration and interdisciplinary learning are fundamental aspects of the collaborative virtual environment, setting it apart from traditional educational approaches (Lange & Smith, 2014). By connecting students from diverse engineering disciplines within a shared virtual space, the environment fosters collaboration and provides opportunities for interdisciplinary problem-solving. This chapter explores the methods and techniques used to promote collaboration and interdisciplinary learning within the virtual environment.

The virtual environment facilitates real-time interaction between users, regardless of their physical location. This virtual collaboration transcends the limitations of traditional physical classroom settings, encouraging dialogue, knowledge sharing, and the exchange of ideas. Students have the opportunity to collaborate on projects and assignments, participate in discussions, and offer feedback to their fellow peers (Dennis & Heeren, 2014). This real-time interaction promotes an active learning environment where ideas are shared, debated, and refined collaboratively.

Through collaborative problem-solving activities, students work together to tackle complex engineering challenges. They form teams, leveraging their collective knowledge and expertise to develop innovative solutions. This collaborative approach nurtures critical thinking skills, enhances problem-solving abilities, and exposes students to diverse perspectives, thereby mirroring real-world engineering scenarios. For example, in a virtual environment, students from different engineering disciplines can work together to design and optimize a sustainable energy system that integrates various renewable energy sources.

Furthermore, the interdisciplinary nature of the virtual environment fosters knowledge exchange across engineering disciplines. Students from different fields of study contribute their unique perspectives, broadening the understanding and application of engineering concepts. For example, in a project involving geographical data analysis for smart city planning, geography information science students can collaborate with computer science students to develop advanced algorithms and data visualization techniques to optimize urban infrastructure planning and ensure efficient resource allocation. This interdisciplinary approach promotes a well-rounded education emphasizing collaboration and diversity's importance in addressing real-world engineering problems.

To facilitate collaboration and interdisciplinary learning, the virtual environment can provide tools and features that encourage communication and teamwork. Features like shared whiteboards, video conferencing, and instant messaging enable students to communicate and collaborate effectively, even when physically separated. These tools promote active engagement, meaningful interaction, and the development of teamwork skills, all of which are crucial for success in engineering.

In summary, the collaborative virtual environment fosters collaboration and interdisciplinary learning by harnessing the potential of technology to facilitate connections between students across various engineering disciplines. By facilitating real-time interaction, collaborative problem-solving, and knowledge exchange, this environment nurtures a tight-knit community and empowers students to collectively address intricate engineering challenges. Students develop essential teamwork and communication skills through these methods while gaining a deeper understanding of engineering concepts from a multidisciplinary perspective.

3. EVALUATION AND RESULTS

In order to provide quantitative data to support the qualitative feedback obtained from participants, performance metrics were recorded during the experiments. A comparison was made between the collaborative virtual environment and traditional learning methods in terms of task completion time, accuracy, and overall performance. With the 2020 undergraduate students majoring in Spatial Information and Digital Technology at Chongqing University of Posts and Telecommunications as the target audience of the course, a total of 26 students were randomly divided into two groups: the online-offline mixed group (observation group) and the offline group (control group), with 13 students in each group.

Usability is an essential element in Human-Computer Interaction (Alkoblan & Abdullah, 2023). The data presented in Table 1 highlights the differences in performance between the collaborative virtual environment and traditional learning methods. The average task completion time in the virtual environment was significantly shorter than in traditional learning methods ($p < 0.05$). This signifies that participants could complete tasks more quickly within the virtual environment.

The virtual environment's accuracy rate was higher than traditional learning methods. This further reinforces the notion that participants could make more precise and accurate decisions within the virtual environment.

Table 1: Performance Evaluation Metrics

Metric	Observation group	Control group
Average Task Completion Time (secs)	13.7	25.1
Accuracy Rate (%)	87.4	73.2

Additionally, participants' subjective feedback regarding usability and user satisfaction was collected through questionnaires. Table 2 provides a summary of the results.

Table 2: User Satisfaction Ratings

Metric	Observation group	Control group
Ease of Use	4.6	3.8
User Interface	4.5	3.8
Engagement	4.8	4.0
Overall Satisfaction	4.7	3.9

These ratings indicate high user satisfaction with the collaborative virtual environment. Participants reported that the platform was easy to navigate, showcasing an intuitive and user-friendly interface. The level of engagement experienced within the virtual environment was also rated highly, indicating that participants felt immersed and motivated to participate in the tasks actively.

Overall, the experiment results demonstrate the effectiveness and usability of the collaborative virtual environment in enhancing engineering education. The quantitative data support the qualitative feedback gathered, validating the benefits of immersive visualization, interdisciplinary learning, and collaboration within the virtual environment. The findings highlight the potential of the collaborative virtual environment as a valuable tool for engineering education, fostering more profound understanding, improved decision-making, and increased learner satisfaction.

4. DISCUSSION

The virtual environment offers unique opportunities for collaboration and interdisciplinary learning. Students from different engineering disciplines can collaborate in virtual teams to work on a typical project or solve complex engineering problems. This collaboration allows them to leverage their diverse perspectives and knowledge, resulting in innovative solutions that draw upon multiple disciplines. For example, a team of electrical engineering, mechanical engineering, and computer science students can collaborate on designing an autonomous vehicle, combining their electronics, mechanics, and programming expertise.

The virtual environment breaks down the barriers of physical distance, enabling global collaboration and knowledge exchange. Students can connect with peers and experts from different universities or countries to share ideas, discuss concepts, and seek guidance. This global perspective exposes students to various cultural and educational backgrounds, broadening their understanding of engineering practices and promoting a more inclusive and diverse learning experience.

Furthermore, the virtual environment offers the advantages of flexible and personalized learning experiences. Students can conveniently access course resources, customizing their learning journey according to their specific needs and interests. They can dive deeper into specific topics, explore additional resources, and engage in self-directed learning. This flexibility empowers students to assume responsibility for their education and fosters a culture of lifelong learning, a valuable competency in the constantly evolving realm of engineering. Integrating immersive visualization within the virtual environment enhances understanding by providing students with a tangible and interactive representation of engineering concepts. Through 3-D visualizations and simulations, students can observe and manipulate complex phenomena, gaining a deeper understanding of their underlying principles. For example, in a civil engineering course, students can virtually construct and test different architectural designs, observing how structural elements interact and analyzing their impact on the structure's overall stability.

Furthermore, immersive visualization enables students to explore real-world engineering scenarios in a safe and controlled environment. They can simulate various operating conditions, test hypotheses, and evaluate different solutions without the risk of real-life consequences. This hands-on experience fosters critical thinking skills and problem-solving abilities as students learn to identify challenges, analyze data, and make informed decisions based on their observations. The collaborative virtual environment also fosters a sense of community among engineering students. Through online forums, discussion boards, and virtual meetings, students can connect with their peers, exchange ideas, and provide feedback on each other's work. This sense of community cultivates a nurturing learning environment that encourages students to seek assistance, share accomplishments, and engage in collaborative projects.

Overall, integrating a collaborative virtual environment in engineering education brings numerous benefits, including expanding interdisciplinary knowledge, opportunities for global collaboration, personalized learning experiences, and enhanced visualization and simulation capabilities. By leveraging the power of technology, educators can create an immersive and interactive learning environment that prepares students for the challenges and opportunities in the field of engineering. Engineering education must adapt and embrace these innovative approaches as the area continues to evolve to foster the next generation of skilled and adaptable engineers.

5. CONCLUSIONS

The virtual environment's ability to break down physical barriers and facilitate global collaboration opens new possibilities for students to connect with peers and experts from different backgrounds and cultures. This promotes a diverse and inclusive learning experience, where different perspectives and ideas are shared, and solutions are developed by synthesizing interdisciplinary knowledge.

Moreover, the integration of immersive visualization techniques enhances understanding and encourages students to engage in hands-on learning. Visualizing, manipulating, and simulating complex engineering concepts in a safe and controlled environment empowers students to apply their knowledge to real-world situations. This experiential learning approach fosters critical thinking and problem-solving skills, preparing students to overcome challenges and adapt to the ever-changing demands of the engineering field.

Furthermore, the collaborative virtual environment promotes a sense of community among engineering students. Through online platforms and tools, students can connect, collaborate, and support each other in their learning journeys. This sense of belonging and shared purpose enhances the studying experience and fosters a supportive environment where students can learn from one another and grow academically and professionally.

In conclusion, integrating a collaborative virtual environment in engineering education holds great promise in preparing students for the opportunities and challenges of the future. By embracing interdisciplinary learning, immersive visualization, and fostering a collaborative community, educators can empower students to become skilled and adaptable engineers. This virtual learning environment not only enhances understanding but also nurtures critical thinking, problem-solving, and teamwork skills, equipping students to excel in their careers and contribute to the advancement of society. As the engineering field continues to evolve, educational institutions must embrace these innovative approaches to ensure the success and growth of future engineers.

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AUTHORS

Jiangfan Feng* received his Ph.D. in Cartography and Geographic Information Systems at Nanjing Normal University, Nanjing China, in 2007. He is currently a professor at Chongqing University of Posts and Telecommunications. His research interests include video GIS, and computer vision.

Yanjie Gong graduated with a Bachelor's Degree in Intelligent Science and Technology from Chongqing University of Posts and Telecommunications in 2022. She is currently pursuing a Master's degree at the same university. Her research interests primarily encompass remote sensing and computer vision.