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Original article

Research on the application effectiveness of VRTSS blended innovative teaching model in higher education

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Abstract:
Objective: To investigate the application effects of the blended innovative teaching model integrating Virtual Reality Technology and Scene Simulation (VRTSS) in higher education. Methods: A cohort of 100 undergraduates from Zhengzhou University were randomly assigned to a control group (traditional teaching) or an experimental group (VRTSS-based blended teaching). The theoretical knowledge test scores, practical skill levels, and teaching satisfaction were compared among the two groups. Results: Compared with the control group, the experimental group demonstrated higher theoretical scores ($P<0.001$), practical skill scores ($P<0.001$), and teaching satisfaction ($P<0.001$). Subjective evaluations further confirmed superior outcomes in stimulating learning interest, enhancing initiative, improving thinking ability, good interactivity, and enhancing teamwork ($P<0.05$). Conclusion: The VRTSS blended teaching model enhanced the professional knowledge level and practical skills of undergraduate students, also improved teaching effectiveness and satisfaction, stimulated students' interest in learning, and fostered their abilities in self-directed learning and problem-solving in contexts. This innovative teaching model holds significant value and implications for optimizing higher education teaching models and enhancing educational quality.

1. Introduction

The rapid development of information technology and evolving educational concepts present significant challenges to traditional teaching methodologies (Pinto & Segura, 2025). In undergraduate education, cultivating students' higher-order thinking skills, including critical thinking, problem-solving abilities, and innovation capabilities, has become a key focus of educational reform (Roberts, 2014; Brown et al., 2020; Pelletier et al., 2022). The digital age is a new era driven by innovation, encompassing educational innovation under the concept of higher education reform. Blended learning (Gu et al., 2025), as a product of the deep integration of information technology and traditional classrooms, has gradually attracted the attention and application of educators (Kumar et al., 2021). It organically combines online and offline teaching, leveraging the advantages of face-to-face interaction in traditional classrooms while utilizing the rich, convenient, open, and flexible

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characteristics of digital resources, thereby enhancing teaching efficiency and quality. Virtual Reality (VR) technology (Rubio-Tamayo et al., 2017) creates a three-dimensional simulated environment through computers to facilitate human-computer interaction, providing an immersive experience. It has been widely applied in various fields, including military, healthcare, entertainment, fashion, business, sports, and media. In education (AlGerafi et al., 2023), VR can expand the scope of traditional classroom teaching (Javaid et al., 2024), transforming the methods of teaching and learning (Alfarsi et al., 2020), allowing students to learn in an immersive environment (Al-Ansi et al., 2023). Based on this, a new blended teaching model combining Virtual Reality Technology and Scene Simulation (VRTSS) has emerged. This model builds upon traditional teaching methods by collecting real and typical cases based on the curriculum, using data collection and processing, and the collaboration between web browsers and VR devices to create virtual scenes. It is characterized by visualization, strong interactivity, practicality, and initiative, effectively demonstrating operational steps and enhancing decision-making and practical thinking skills. In VRTSS classes, students use VR-related technology to experience pre-set practical scenarios, gradually gaining a deeper understanding of the content through continuous operation, interaction, and feedback, thus creating a positive learning experience. This innovative teaching model provides an efficient learning platform for undergraduate students, stimulating their interest in learning. By organically integrating "theory-practice-reality", it aims to break the constraints of time and space, guiding students into situational learning. This approach promotes active participation and personalized learning, enhancing students' overall quality and practical skills, and laying a solid foundation for their future studies and careers (Holt, 2023). However, there is currently a lack of systematic analysis and evaluation of the actual application effects of the VRTSS blended teaching model in higher education. This study, based on actual teaching cases, systematically explores the application effects of the new blended teaching model of VRTSS in higher education, focusing on its impact on students' learning interest, knowledge mastery, and autonomous learning ability. Designed to provide theoretical support and practical guidance for higher education teaching reform, promote the deep integration of information technology and higher education, and enhance the quality of talent cultivation.

2. Methods

2.1 Study population

A total of 100 undergraduate students (50 males and 50 females, aged 17-20 years) , were randomly selected from Zhengzhou University in 2024. On the basis of informed consent, they were assigned to the traditional teaching group (control group), with a mean age of 18.12±0.72, and the VRTSS-based blended learning group (experimental group), with a mean age of 17.96±0.60 years, based on stratified cluster randomization. This allocation ensured complete comparability between the two groups in terms of gender (25 males and 25 females in each group), with 50 participants per group. When comparing the general data of the two groups, no statistically significant differences were found ($P>0.05$).

2.2 Teaching methods

Two groups of undergraduate students were taught by the same experienced instructor during the same period. The teaching integrated theoretical knowledge with practical case studies, and the content was strictly in accordance with the syllabus, ensuring consistency across both groups. The only difference between the groups was the teaching method employed. All research subjects were ensured to be fully engaged in the teaching process.

2.2.1 Traditional teaching mode of the control group

According to the teaching syllabus of Zhengzhou University, the unified teaching content is formulated, and the teachers adopt the traditional teaching mode to teach. The classroom is mainly taught by the teachers, supplemented by students' listening and recording, and practical skills operation training is carried out. After-class review materials were arranged for the students, who were required to independently complete the summarization of key points and consolidation of knowledge.

2.2.2 New teaching mode of experimental group

The VRTSS blended teaching model is based on the existing curriculum, where teachers integrate typical case studies to construct realistic scenarios within a VR platform. This training aims to familiarize students with the application of virtual reality technology and the operation procedures of the VRTSS platform. Students participate in simulated scenarios by wearing virtual reality devices. After the scenario simulation, students summarize the case, followed by teachers' feedback and analysis. The emphasis is on enhancing students' immersive experience and sense of operational involvement, thereby facilitating their understanding of processes. The specific process is as follows: (1) Based on the teaching syllabus, design the teaching content. Utilize virtual reality technology for scenarios simulation, ensuring the integrity, rationality, and smoothness of the simulated scenarios; (2) Teachers conduct a preliminary experience of the simulation from the students' perspective, summarize the issues encountered during the experience, and further refine the teaching content and process; (3) Establish learning groups for the experimental cohort, with each group consisting of 10 students. Organize students to actively participate in the simulation, where they engage in hands-on practice, group discussions, and information retrieval to independently solve problems and conduct self-summaries; (4) Conduct offline teaching, where teachers analyze students' self -summaries and the issues encountered during simulation operations. They guide students in thinking and discussion, clarify students' doubts, and offer reasonable suggestions; (5) Design a skills operation scoring sheet and a satisfaction survey questionnaire for the VRTSS hybrid new teaching model to assess the teaching effectiveness.

Table 1. Comparison of subjective evaluations of teaching effectiveness across different teaching models.

Evaluation content	Control group (n = 50)		Experimental group (n = 50)		*p*
	satisfied	unsatisfied	satisfied	unsatisfied	
Stimulating interest in learning	36 (72.00%)	14 (28.00%)	44 (88.00%)	6 (12.00%)	0.046
Enhancing initiative	34 (68.00%)	16 (32.00%)	45 (90.00%)	5 (10.00%)	0.007
Improving thinking ability	37 (74.00%)	13 (26.00%)	46 (92.00%)	4 (8.00%)	0.017
Good interactivity	34 (68.00%)	16 (32.00%)	44 (88.00%)	6 (12.00%)	0.016
Richness of course content	35 (70.00%)	15 (30.00%)	40 (80.00%)	10 (20.00%)	0.248
Enhancing teamwork	37 (74.00%)	13 (26.00%)	45 (90.00%)	5 (10.00%)	0.037

2.3 Indicators of investigation

The teaching and training lasted for two weeks. After each group completed the teaching content, a summary was conducted along with student Q&A sessions to ensure the smooth progress of the teaching tasks. At the end of the teaching period, 100 undergraduate students from both the control group and the experimental group were asked to conduct self-assessment and evaluate their satisfaction with the teaching. They also underwent a unified examination of theoretical knowledge and practical skills. Teachers evaluated the teaching effectiveness based on the scores of the theoretical and practical skills assessments.

2.3.1 Subjective evaluation

The subjective evaluation of undergraduate students' teaching effectiveness is primarily conducted through questionnaires. The questionnaire covers six aspects: learning interest, initiative, thinking ability, classroom interactivity, richness of course content, and teamwork. The evaluation conclusions include two categories: "improvement observed" (satisfied) and "not significant" (unsatisfied), with the number of students in each category being tallied. In addition, the satisfaction of the two groups of undergraduate students with the teaching methods they received is surveyed, with a full score of 100 points.

2.3.2 Objective evaluation

The objective evaluation consists of two parts: theoretical assessment and skills assessment. The theoretical assessment is designed to evaluate the undergraduate students' grasp of basic knowledge. After the completion of the learning period, a unified assessment is arranged for both the control group and the experimental group, comprising a total of 100 undergraduate students. Both groups take the same exam at the same time using the same set of test papers. The examination is conducted in a closed-book format, and the grading is carried out using a fair and uniform scoring standard. The skills assessment is conducted after the learning period for both groups of undergraduate students through a unified practice skills evaluation. This assessment covers five major aspects: mastery of basic knowledge, proficiency in practical skills, integration of theory with practice, use of teaching equipment, and overall quality development. Each teacher is assigned to evaluate one specific practical skill assessment item to ensure the objectivity and fairness of the scoring. Each item is scored out of 100 points.

2.4 Statistical methods

The research data were analyzed and organized using SPSS 27.0 software. For quantitative data, a t-test was employed. The results were statistically analyzed and presented as mean ± standard deviation, the difference was statistically significant ($P<0.05$).

3. Results

3.1 Comparison of Subjective Evaluation of Teaching Effectiveness Under Different Teaching Models

The subjective evaluations of teaching effectiveness by two groups of undergraduate students were primarily conducted through questionnaires, with a response rate of 100%. The evaluation content included stimulating learning interest, enhancing initiative, improving clinical thinking ability, good interactivity, richness of course content, and enhancing teamwork (Table 1). The chi-square test was used to compare the differences in satisfaction between the two courses. The results showed that the experimental group of undergraduate students

Table 2. Comparison of undergraduate students' satisfaction with different teaching modes.

Evaluation content	Control group	Experimental group	*P*
Teaching satisfaction score	79.12±10.79	90.38±7.84	<0.001

Table 3. Objective evaluation results of undergraduates under two different modes.

Evaluation content	Control group	Experimental group	*P*
Mastery of basic knowledge	80.08±10.80	81.00±11.53	0.68
Proficiency in practical skills	84.24±7.51	88.20±6.21	0.027
Integration of theory with practical situations practical situations	22.10±2.77	24.78±2.72	<0.001
Total score	78.39±4.84	87.44±4.84	<0.001

had more significant improvements in stimulating learning interest, enhancing initiative, improving clinical thinking ability, interactivity, and enhancing teamwork. Comparing the differences in the six dimensions of satisfaction between the two different teaching models, after Bonferroni correction (α=0.05/6), it was found that the VRTSS model significantly outperformed the control group in enhancing initiative ($P<0.05$).

3.2 Comparison of undergraduate teaching satisfaction under different teaching modes

The comparison of teaching satisfaction was conducted through a questionnaire survey, investigating the teaching satisfaction of the two groups of undergraduate students, with the results shown in Table 2. The Mann-Whitney U test was employed, revealing that the average satisfaction score of the experimental group using the VRTSS model was significantly higher than that of the traditional teaching model used by the control group, with the difference being statistically significant (***$P<0.001$).

3.3 Objective evaluation of teaching effect under different teaching modes

The teaching effectiveness of the two groups of undergraduate students in this study was assessed in two major aspects: theoretical knowledge and practical skills. The theoretical knowledge assessment was reflected through examination scores, while the practical skills assessment mainly included five aspects: mastery of basic knowledge, proficiency in practical skills, integration of theory with practice, use of teaching equipment, and overall quality development. The full score for each aspect was 100 points, with the overall quality development scoring a maximum of 10 points. The experimental group was awarded a full score of 10 points for the use of teaching equipment based on the actual classroom situation, while the control group received 5 points. The results are shown in Table 3. The Mann-Whitney U test and independent samples t-test were used for analysis. Students in the VRTSS model demonstrated significant performance in proficiency of practical skills and integration of theory with practice. The overall objective teaching effectiveness of the VRTSS model was significantly better than that of the control group, with the results being statistically significant (***$P<0.001$).

4. Discussion and Conclusion

The ongoing development of VR technology has provided new methods and techniques for the education (Kamińska et al., 2019) and training of talents in various disciplines, including philosophy, economics, law, education (Shahab et al., 2022), medicine (Gårdling et al., 2025), engineering (Soliman et al., 2021) and more. In previous studies, scholars have applied virtual reality technology to special children's education, operating room teaching, and table tennis training, achieving ideal educational outcomes. At the 16th International Conference on Education and New Learning Technologies, F. De Lorenzis et al. presented a VR Training Systems (VRTSs) for training CBRN (Chemical, Biological, Radiological, Nuclear) operators in the Recce procedure. The system was initially tested against the backdrop of the NATO's "Toxic Trip 2023" event and achieved good results. At the time, the CBRN instructor can improve the overall training experience (De Lorenzis et al., 2024). The dec-reasing prices of VR devices have created favorable conditions for the widespread adoption of the VRTSS blended teaching model. By integrating with scenario simulation, this approach places students at the center, immersing themselves in realistic scenarios, offering them a novel and authentic learning experience. The application of the VRTSS blended learning model addresses the challenges of traditional teaching methods, namely the difficulties of "inaccessibility, invisibility, immobility, and irreproducibility". It offers undergraduate students an i-mmersive learning experience and enhances their self-directed learning abilities.

The results of this study indicate that the VRTSS blended teaching model outperforms the traditional teaching group in terms of subjective evaluation, objective evaluation, and teaching satisfaction ($P<0.05$), thereby affirming the value and significance of the new teaching model in enhancing teaching quality. Firstly, the VRTSS blended learning model transcends the limitations of human resources, time, space, and resources (Gong et al., 2025; Lee et al., 2022; Liu, 2025), providing undergraduate students with a portable platform

for learning and communication that meets their educational needs. Secondly, by integrating virtual reality technology with scenario simulation, students can immerse themselves in real-world scenarios and practice operational drills, thereby enhancing their ability to apply knowledge, practical skills, and logical thinking, thus laying a solid foundation for their future careers and studies. Lastly, the application of virtual reality technology in education enables undergraduate students from different regions and universities to access the same high-quality teaching content, promoting the sharing of teaching resources, cultivating more high-quality talents, and advancing the reform of higher education (Marougkas et al., 2023).

The application of the VRTSS blended teaching model in undergraduate education has expanded teaching resources and platforms, stimulated students' interest in learning, enhanced teaching effectiveness, and received consistent recognition from universities and instructors. Through the implementation of the VRTSS blended teaching model, this study has summarized the necessary conditions and technical support required, which mainly include the following five aspects: (1) Regular Assessment and Improvement of the Teaching Process: understand students' learning experiences with the new teaching model, analyze its strengths and weaknesses, and continuously optimize the teaching process; (2) Provide Personalized Services For Students: offer diverse and personalized learning support to help students adapt to the new teaching model; (3) Establish Teacher Training Programs: conduct relevant training courses for teachers to help them master and apply virtual reality-related technologies and equipment, thereby improving teaching quality effectiveness; (4) Develop a Stable Virtual Reality Learning Platform: establish and maintain an advanced and stable learning platform and technical equipment, while ensuring the security of the learning platform and data protection; (5) Optimizing Teaching Resources: the quality of teaching resources directly affects teaching effectiveness. It is essential to evaluate and update teaching resources regularly to ensure the novelty and interest of the teaching content, meet students' learning needs, and enhance teaching effectiveness. The VRTSS blended teaching model is innovative, but we should also recognize its limitations (Holmes & Tuomi, 2022). First, since this model emphasizes the initiative of undergraduate students, it poses a significant challenge for those accustomed to traditional teaching methods. If students lack initiative (Tang et al., 2021), this new teaching model may offer limited benefits for their personal development. Second, the new teaching model may require more effort and time from teachers. In addition to providing offline guidance to students, teachers also need to design scenario simulations and organize resources on the virtual teaching platform. They may also be required to participate in relevant teaching training sessions. Finally, the equipment costs associated with the VRTSS blended teaching model are relatively high (Javaid et al., 2024), and some undergraduate students may face the situations where their institutions cannot provide the necessary basic equipment. Moreover, the variety of related teaching resources is limited, and updates are slow. Some aspects of the interactive and operational environment design are not reasonable. There is a need for more communication (Millán et al., 2022) between relevant enterprises and universities to address the actual needs in teaching work.

In summary, the application of the VRTSS blended teaching model in undergraduate education has filled the gaps in traditional teaching, enhanced students' learning outcomes and satisfaction, enriched the teaching content, and achieved significant teaching effectiveness. Although the integration of virtual reality technology with teaching is not yet fully mature, continuous improvement and exploration will undoubtedly enable this new teaching model to better serve higher education. It will greatly enhance teaching effectiveness and provide society with more high-quality talents.

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Conflict of interest

The authors declare no conflict of interest.

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