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A Study on the Construction of Virtual Simulation Experiments for Basketball Projects

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Abstract. Virtual simulation experiments, as a new teaching method and approach, have gradually been introduced into higher education and received recognition from a large number of education professionals. Considering the successful application of virtual simulation experiments in other disciplines, this study aims to employ virtual simulation technology to construct a virtual simulation experiment for basketball projects, with the goal of promoting the application of virtual simulation technology in sports and health education. The main research methods employed in this study include expert interviews, questionnaire surveys, and software development approaches. A questionnaire survey was conducted among 230 students from six universities, and interviews were conducted with 15 relevant individuals. The demands and requirements of university teachers and students regarding virtual simulation experiments for basketball projects were summarized and refined. The experiment was developed using 3D Studio MAX and Maya as modeling tools. Finally, all aspects of this research were completed through functional validation and application effectiveness evaluation. In the survey stage of needs assessment, a total of 230 questionnaires were collected from six universities. Among them, 63.63% of students claimed to have a relatively good understanding of virtual simulation experiments, 78% of students considered virtual simulation experiments to be of significant importance in teaching, and 84.71% of students regarded this teaching method as relatively relaxed. The development process involved the development of six modules, and after the completion of each module, Unity 3 was used for integration, resulting in the completion of the experiment. Subsequently, functional validation of the virtual simulation was conducted, achieving a 100% pass rate in the testing of various scenarios. An effectiveness evaluation questionnaire was utilized, and the scores from the six dimensions and 20 indicators ranged from a minimum of 3 to a maximum of 5, indicating that university students generally recognized and were satisfied with various aspects of virtual simulation experiments. The construction and application of virtual simulation experiments in China are still in the initial stages, primarily focusing on theoretical research. The virtual simulation experiments were categorized into six sections: basic theoretical learning, technical and tactical application, physical fitness, presentation and competition, rules and refereeing, and observation and evaluation. Various test scenarios were established to assess the interface, performance, and functionality, and both functional validation and application effectiveness evaluation questionnaires yielded positive results. These findings strongly support the assertion that the virtual simulation experiment constructed in this study can serve as an effective supplementary tool for basketball teaching in universities.

Key words: basketball; design and development; virtual simulation experiment

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INTRODUCTION

With the development of information technology, emerging technologies such as big data, cloud computing, and machine learning are appearing successively along with the rise of the sharing economy. Under this circumstance, traditional sports and health education is facing new challenges. Virtual simulation experiments, as a new teaching method and approach, can effectively expand the temporal, spatial, and learning pathways for sports and health education in higher education. Therefore, one of the current research focuses in higher education sports and health teaching is how to effectively construct virtual simulation experiments for sports in accordance with the current policies and systems of sports and health education in China.

Virtual simulation-based sports teaching and training platforms offer various functionalities, including enhancing students' interest in learning, monitoring the learning and training processes, expanding learning

spaces, and creating diverse learning pathways. For example, in baseball teaching, virtual simulation experiments can effectively increase students' interest in self-directed learning of baseball and enhance their application abilities in practical situations (Yang et al., 2021). In basketball teaching, capturing students' motion information and utilizing three-dimensional simulations enable full monitoring of students' learning and training processes (Yin, 2018). In Tai Chi projects, students can engage in autonomous learning of Tai Chi through virtual simulation systems, thereby improving the skill levels of Tai Chi learners (Du, 2014). In table tennis, the use of virtual simulation technology contributes to the construction of new knowledge (Yang, 2014). Leveraging the advantages of immersion, interactivity, and realism provided by virtual simulation experiments can effectively compensate for issues such as limited training conditions and monotonous teaching formats, helping to enhance students' interest in learning sports skills and expand the space and pathways of learning.

The construction of virtual simulation experiments requires theoretical support from various teaching theories, including integrative educational management theory (Zu, & Yan, 2021), smart education theory (Mao, 2021; Zhong et al., 2018), connectivism (Zeng, 2020), and constructivist teaching theory (Jiang, 2012). Commonly used tools for virtual simulation experiments involve 3D Studio Max and Maya as modeling tools for creating experimental models and interactive scenes (Yang et al., 2021). The final integration is achieved using Unity 3D, with four layers including the data layer, management layer, interaction layer, and perception (simulation) layer (Chi et al., 2021), following the principle of the lower layers serving the upper layers. Users mostly interact through web browsers to meet the requirements of teaching.

The application of virtual simulation experiments in the field of sports mainly focuses on sports and health education and sports training. Han Li et al. applied motion capture technology to volleyball teaching, establishing a real-time interactive virtual training system. Through a comparison with conventional teaching, they found that the introduction of motion capture technology in volleyball teaching helps break away from the traditional reliance on theoretical learning and improves the quality of teaching (Han & Liu, 2015). Zhong Xin et al. used motion capture technology in athlete training to analyze athletes' motion techniques in real-time by collecting technical motion data during training (Zhong & Yang, 2009). Liu incorporated Kinect devices into a virtual mass sports teaching demonstration system for motion capture, reconstruction, and comparative analysis. The collected motion data was compared with standard movements and used for feedback in teaching (Liu, 2014). Jennifer C. Reckell et al. demonstrated through a 9-week intervention experiment that virtual environments effectively enhance training effects and reduce injury rates in college soccer, improve control and balance in neck nerve movement, and provide evidence of positive transfer from virtual to real environments. They support the use of these new virtual practice methods to improve sensory motor control measures for soccer players (Reneker et al., 2020). Stefan C. Michalski et al. proved that using VR virtual environments in sports training allows for the transfer of skills from the virtual to the real world (Michalski et al., 2019). Many scholars have affirmed the feasibility and future prospects of applying virtual simulation experiments to sports and health education for learning sports skills.

With the development trend of educational informatization during the 14th Five-Year Plan, emerging technologies such as "motion capture" and "gesture recognition" will undoubtedly have broader applications in sports skill learning and play an important role in expanding the digital resources of higher education sports and health education (Zhou et al., 2020). By consulting the National Experimental Space (iLAB), it was found that there are only 28 virtual simulation experiments available in the field of sports, mainly for learning sports theory knowledge. These experiments involve simple interactions through text, images, animations, and videos using a mouse and keyboard, such as "Virtual Simulation Experiment for Table Tennis Referees (bilingual)" and "Virtual Simulation Experiment for Intervention in Abnormal Spinal Curvature Motion in Adolescents." Physical practice is a primary means in the field of sports, which is a highly practical discipline. Learning sports skills requires processes such as generalization, differentiation, and automatization, necessitating multiple practice sessions for students to master them.

Furthermore, in current Chinese universities, physical education teachers mostly rely on experience-based teaching methods in sports and health education. They teach and guide students based on their previous training, competition, and teaching experiences, helping students grasp the essentials of movement skills (Zhan & Gong, 2014). Students learn relevant sports skills by observing the teacher's demonstration. However, this approach can lead to deviations between the teacher's demonstration and the student's understanding. After multiple demonstrations, teachers may experience physical fatigue, resulting in a series of problems such as decreased precision, inconsistency, and deformation of the demonstration movements. These issues can also affect the effectiveness of students' sports skill learning (Xing, 2018).

Therefore, how to effectively address the series of issues faced in college basketball teaching, improve the level of educational informatization, and overcome the lack of interactivity and immersion in virtual simulation

experiments becomes the focus of this research. This study aims to construct a virtual simulation experiment for basketball and introduce motion capture technology into the developed virtual simulation experiment. By enhancing interactivity and immersion and fully utilizing modern information technology, it seeks to create an effective auxiliary tool for college basketball teaching.

METHOD

Study design and participants

The design of this study followed the principles of the Helsinki Declaration and was approved by the Human Research Ethics Committee of East China Normal University (Approval No: HR 739-2022). In October 2022, a needs assessment was conducted among 230 students from six universities, including East China Normal University, Henan University of Technology, and Zhengzhou University of Finance and Economics. The needs assessment employed questionnaires, expert interview outlines, and effectiveness evaluation questionnaires as research tools. Development of the virtual simulation experiment was carried out using 3D Studio Max and Maya as development tools, and Unity3D as the integration tool.

The expert validity scores for the needs assessment questionnaire were all above 4 (out of 5), and the test-retest reliability was 0.804. The expert validity scores for the interview outlines were all above 4 (out of 5), and the expert validity scores for the effectiveness evaluation questionnaires were also above 4. The standardized Cronbach's alpha coefficient was 0.947. Based on the needs assessment, the content, structure, and functionality of the virtual simulation experiment for basketball were designed. Each module was developed separately and then integrated for final release, completing the development of the experiment. Finally, performance testing and evaluation of application effectiveness were conducted to validate the functionality and effects of the virtual simulation experiment constructed in this study.

Needs Assessment

Based on the reference to existing literature, the "Basketball Skill Learning Virtual Simulation Experiment Needs Assessment Questionnaire" (Gao, 2020; Zhong, 2019; Shao, 2018) was designed. It consists of four sections: personal information, virtual simulation experiment awareness survey, college student basketball learning survey, and needs assessment. The personal information section investigates students' gender, grade, and major (total: 3 questions). The virtual simulation experiment awareness survey assesses students' knowledge and experience with virtual simulation experiments, as well as their feedback on using them (total: 10 questions). The basketball learning survey examines whether students encountered any difficulties in learning basketball skills (total: 2 questions). The needs assessment section investigates students' demand for basketball project virtual simulation experiments (total: 6 questions, 5 multiple-choice questions, and 1 open-ended question). Interviews were conducted with experts in the field of virtual simulation experiment course construction and university basketball teachers. The interview outlines were divided into two main dimensions: interview outline for experts in virtual simulation experiment course construction and teaching, and interview outline for university basketball teachers. Each main dimension consisted of 1-6 interview questions, totaling 10 questions. Discussions and justifications were conducted on the significance and content of virtual simulation experiment construction, management approaches, involved content and actions, and development technologies.

Software Development and Function Testing

Using software development methods, the designed virtual simulation experiment was transformed into an information-based format. Basic knowledge and technical actions were presented through text, images, videos, and modeling. Human-computer interaction was achieved using keyboard, mouse, and gesture recognition technologies. The development was carried out using popular modeling tools such as Maya and 3D Studio Max. A web-based system architecture was designed, and the database was deployed to complete the construction of the virtual simulation experiment.

The virtual simulation experiment was tested for interactivity, functionality, and stability from the perspectives of interface, functionality, and performance. Interface testing mainly assessed the smooth operation of the interactive interface and the functionality of clickable elements. Functionality testing focused on whether the functional design matched the actual development and achieved the intended functionality, resulting in a good interactive effect. Stability testing examined whether the experiment platform experienced lag or instability during operation and whether it performed smoothly under high concurrency.

Effect Validation

The study utilized an adapted questionnaire, the "Application Effect Evaluation Questionnaire for Basketball Skill Learning Virtual Simulation Experiment," as the survey tool. Students had a 30-minute autonomous experience in the laboratory, followed by an online (email, WeChat, QQ, etc.) survey of college students to assess the application's effectiveness. The application effect evaluation questionnaire included six primary dimensions and 20 secondary indicators: immersion, learning interaction, perceived usability, perceived usefulness, learning motivation, and learning intention. The questionnaire aimed to provide data support for the subsequent application, promotion, optimization, and improvement of the experimental platform.

RESULT AND DISCUSION

Results of Needs Assessment

A total of 230 questionnaires were collected, and after data cleaning and organization, 224 valid responses were obtained. The specific results analysis is as follows:

College students have a certain level of awareness of virtual simulation experiments. 63.63% of the students reported having knowledge of virtual simulation experiments. 78% of the students believe that virtual simulation experiments are important for teaching. 84.71% of the students find this teaching method to be relaxed, and 86.44% of the students enjoy this teaching approach. It is generally believed that virtual simulation experiments are helpful for teaching, and most students are willing to accept or prefer this teaching method.

Virtual simulation experiments have a certain application space in university teaching. Only 33.52% of the students have experience using virtual simulation experiments. 20.59% of the students reported that teachers used virtual simulation experiments during class, while 54.41% used them for pre-class preview, and 52.94% used them for self-study after class. 51.47% of the students believe that virtual simulation experiments can effectively stimulate their interest in the subject, 63.24% believe that they help in practical skill mastery, 52.94% believe they can foster innovative thinking, and 51.47% believe they enhance awareness of proper procedures. 60.29% of the students think virtual simulation experiments contribute to the accumulation of professional knowledge.

College students have a high demand for virtual simulation experiments in basketball skill learning. 88.69% of the students find basketball skill learning somewhat challenging, and 90.78% of the students are willing to use virtual simulation experiments for teaching. 82.48% of the students believe that virtual simulation experiments should be widely used.

College students' demands for the experimental platform mainly focus on theoretical knowledge, basic techniques and skills. 63.59% of the students believe that the virtual simulation experiments developed in this study should cover fundamental theoretical knowledge of basketball. 72.81% believe that basic techniques and skills should be included, 55.30% believe that knowledge of basketball refereeing should be covered, 44.24% think it should involve sports rehabilitation knowledge, 42.86% think it should include relevant fitness knowledge, and 43.78% believe that appreciation of basketball events should be incorporated.

Development of Virtual Simulation Experiment

The development of the guiding module, the "guiding module" of the virtual simulation experiment, generally does not possess actual operational functionality. Instead, it provides an introduction to the virtual simulation experiment and project content, as well as guidance for beginners. By entering the corresponding IP of the virtual simulation experiment, users can access the login interface. New users can click on "Register" and fill in various required information. After entering the account password, they can click on "Login" and select "Basketball" to enter the interface for learning basketball sports skills.

Figure 1. Web page interface display

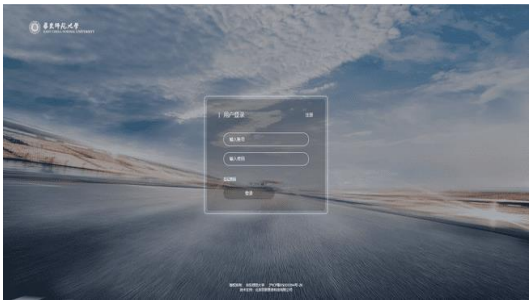

Figure 2. Login interface display

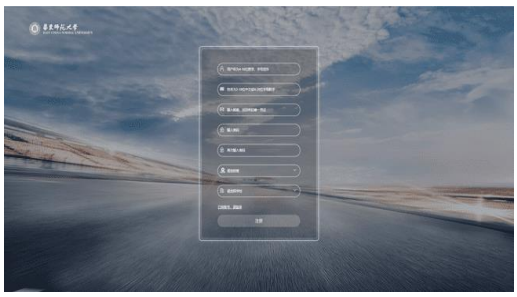

Figure 3. Registration interface display

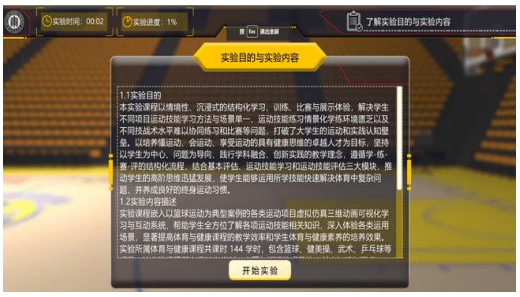

Figure 4. Introduction page display

Development of Experimental Platform Teaching Interaction Module, After the "New User Guide" interface, users will be redirected to the "Teaching Interaction" module. This interface primarily displays the six functional icons of the virtual simulation experiment, namely Basic Theory Learning, Tactical Application, Specific and General Physical Fitness, Demonstration and Competition, Rules and Refereeing, and Appreciation and Evaluation. By clicking on the corresponding icon, users can enter different experimental interfaces.

Figure 5. Main interface display

Figure 6. Basic theory learning display

Figure 7. Dribbling operation display

Figure 8. Cut-in interface display

Figure 9. Gesture recognition display

Figure 10. Viewing and evaluation display

Functional and Application Effect Analysis

To verify that the experimental platform has good interactivity, functionality, and stability, a variety of system test cases were designed for system testing. A total of 66 test cases were set up, including 15 interface tests, 35 functionality tests, and 15 performance tests. The results of the tests showed a 100% pass rate for all tested aspects of the system. The test results demonstrate that the system has good application effects, fully

confirming that the developed "Virtual Simulation Experiment for Sports Skill Learning" in this study can be implemented in daily teaching applications. For detailed test report, please refer to Table 1.

Table 1. Overview of System Functionality Test Results

Test Item	Test Case	Quantity Passed	Quantity Failed Quantity	Pass Rate
Interface Testing	16	16	0	100%
Functionality Testing	35	35	0	100%
Performance Testing	15	15	0	100%

Based on references to existing literature on application effectiveness evaluation scales and questionnaires (Li, 2019; Lau et al., 2017), and in consultation with university basketball teachers and software development professionals, an application effectiveness evaluation questionnaire was designed based on the Technology Acceptance Model (TAM). The aim was to assess the teaching effectiveness and identify any issues related to the application of virtual simulation experiments in basketball teaching through the application effectiveness evaluation questionnaire. This evaluation aims to provide insights and pathways for optimizing and improving the subsequent experimental platform. In the evaluation of the application effectiveness of the experimental platform, a Likert 5-point scale ranging from 1 to 5 was used for positive scoring. Descriptive statistical analysis was primarily conducted to examine the maximum value, minimum value, mean, and other aspects (refer to Table 2) for the assessment.

Table 2. Descriptive Statistical Analysis of Application Effectiveness

Dimension	Question Number	Sample Size	Maximum Value	Minimum Value	Average Value	Standard Deviation	Dimension Average Value	Dimension Standard Deviation
Immersion	A1	30	5	3	4.33	0.63	4.25	0.763
	A2	30	5	2	3.8	0.92		
	A3	30	5	3	4.47	0.73		
	A4	30	5	3	4.4	0.77		
Learning Interaction	B1	30	5	3	4.53	0.68	4.59	0.60
	B2	30	5	3	4.7	0.53		
	B3	30	5	3	4.57	0.57		
	B4	30	5	3	4.57	0.63		
Perceived Usability	C1	30	5	4	4.73	0.45	4.58	0.57
	C2	30	5	3	4.47	0.63		
	C3	30	5	3	4.53	0.63		
Perceived Usefulness	D1	30	5	3	4.37	0.61	4.39	0.63
	D2	30	5	2	4.3	0.70		
	D3	30	5	3	4.5	0.57		
Learning Motivation	E1	30	5	3	4.53	0.68	4.45	0.68
	E2	30	5	3	4.50	0.57		
	E3	30	5	2	4.33	0.80		
Learning Intent	F1	30	5	3	4.50	0.63	4.53	0.61
	F2	30	5	3	4.50	0.63		
	F3	30	5	3	4.60	0.56		

The calculation reveals that the minimum values for the 20 indicators across the 6 dimensions are concentrated around 3, while the maximum values are concentrated around 5. This indicates that college students generally recognize and are satisfied with various aspects of the virtual simulation experiment. Based

on the students' ratings for the dimensions of immersion and learning interaction (all above 4), it can be concluded that students generally acknowledge the high level of immersion and strong interactivity of the virtual simulation experiment constructed in this study. The high ratings for the dimensions of perceived ease of use and perceived usefulness also indicate that participating students generally acknowledge that the virtual simulation experiment facilitates their understanding of the experimental content, makes it easier to remember the process of action demonstration and the display of action skill, and contributes to the correct construction of basketball skills. There are also high scores in the dimensions of learning motivation and learning intention, indicating that participating students generally believe that virtual simulation experiment teaching can enhance their interest in learning and facilitate targeted learning of sports skills.

To further investigate the application effects of virtual simulation experiments and identify potential pathways for optimization, the descriptive statistical data was imported into SPSS 26.0. Multiple regression analyses were conducted to examine the impacts of immersion, learning interaction, perceived usefulness, and perceived ease of use on learning motivation and learning intention. The specific statistical analysis results are presented in Table 3.

Table 3. Results of Multiple Regression Analysis

	Dependent Variable	β (Standard Coefficient)	R^2 Goodness of Fit	Sig. (Significance)
Learning Motivation	Learning Interaction	0.67	0.44	P<0.001
	Immersion	0.53	0.28	0.002<P<0.005
	Perceived Usability	0.35	0.59	P=0.001
	Perceived Usefulness	0.81	0.65	P<0.001
Learning Intent	Learning Interaction	0.65	0.42	P<0.001
	Immersion	0.55	0.31	P=0.001
	Perceived Usability	0.65	0.42	P<0.001
	Perceived Usefulness	0.85	0.72	P<0.001

The immersion, learning interaction, perceived ease of use, and perceived usefulness significantly influence both learning motivation and learning intention. This indicates that learning interaction and perceived usefulness contribute more significantly to learning motivation and learning intention, providing a solid foundation for the future improvement and optimization of virtual simulation experiments and instructional content. Perceived usefulness has the most significant impact on learning intention, highlighting the crucial role of perceived usefulness in the integration of virtual simulation technology and instructional content. This finding suggests the direction for the integration of technology and content in future virtual simulation experiments.

CONCLUSION

Based on the clarification of the needs of university teachers and students, this study constructed a virtual simulation experiment divided into six sections. The experiment underwent functional testing and effect evaluation, with a 100% pass rate for the selected test cases. The maximum value of the application effect evaluation concentrated around 5, the minimum value concentrated around 3, and the average value was greater than 4. This further demonstrates that the virtual simulation experiment constructed in this study can meet the needs of daily physical education basketball teaching in universities. Building upon this foundation, regression analysis was conducted on the data to explore the effects of learning interaction, immersion, perceived usefulness, and perceived ease of use on learning motivation and learning intention. These findings provide data support for the further improvement and optimization of virtual simulation, as well as the exploration of the integration of virtual simulation technology with sports skill learning.

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