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Article

# Integration of virtual reality technology in physical education: A biomechanical approach to enhancing skill mastery and student experience

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**Abstract:** This study explores the integration of Virtual Reality (VR) technology within physical education at higher education institutions, with a focus on its biomechanical implications. VR not only addresses issues like outdated content and monotonous teaching methods but also provides an immersive environment for students to understand the principles of biomechanics through interactive simulations. By improving the understanding of movement patterns and physical interactions at the molecular and cellular levels, VR significantly enhances students' skill mastery and physical fitness. Challenges such as high equipment costs and technical maintenance remain pertinent. Future research should aim to optimize VR content from a biomechanical perspective and integrate it with traditional teaching methods to further advance the field.

**Keywords:** virtual reality; physical education; skill mastery; student engagement; educational innovation

## 1. Introduction

Virtual reality technology, also known as VR technology, is a technology that creates and presents a digital environment highly similar to the real or imagined world through computer technology. This technology allows users to interact with and immerse themselves in it using specific devices. VR technology first emerged in the 1980s and early 1990s, primarily used in fields such as military, manufacturing, and healthcare. In the field of education, although still in the experimental and exploratory stage, it has begun to play a role in higher education and vocational education, involving disciplines such as physics, chemistry, biology, medicine, and engineering, mainly through forms such as virtual experiments, simulations, and games. From the mid-1990s to the early 21st century, VR technology experienced rapid development and widespread popularity, and its application in education gradually expanded to primary and secondary education, covering subjects such as history, geography, culture, and arts, mainly through virtual scenes, tours, and storytelling. Since the early 21st century, the integration of VR technology with emerging technologies such as the internet, big data, and artificial intelligence has brought new opportunities and challenges to the field of education, driving innovation and transformation in educational applications. Currently, the disciplines and fields involved in education are more extensive and diverse, primarily achieved through forms such as virtual communities, role-playing, and teaching systems. In the field of basic education, VR technology is mainly applied to experimental and

demonstrative courses in physics, chemistry, biology, and geography, by constructing virtual laboratories and teaching environments to enhance students' learning interest and effectiveness. For example, Haidian District Experimental Primary School in Beijing implemented a "VR + Geography" course, allowing students to experience the natural landscapes and cultural features of different regions through VR glasses, thus enhancing the fun and realism of geography learning. In higher education, VR technology is mainly applied to practical teaching sessions in medicine, engineering, and arts, by constructing virtual simulation laboratories and training and design platforms to improve students' professional skills and innovation capabilities. Tsinghua University's "VR + Architecture" course is an example, where students use VR glasses for architectural design and presentation, thereby improving the efficiency and quality of architectural design. In vocational education, VR technology is mainly applied to vocational skills training in automotive, electric power, welding, and mechanical fields, by constructing virtual simulation training and assessment systems to improve students' professional literacy and employability. For instance, the VR intelligent driving training pilot in Beijing allows examinees to conduct virtual driving training through stereoscopic VR glasses in a simulated cockpit, thereby enhancing driving safety and learning efficiency. These examples of vocational education fully demonstrate the great potential of VR technology in practical teaching in higher education.

## 1.1. Research background and purpose

Higher sports institutions in China bear the responsibility of cultivating multifaceted sports professionals capable of engaging in sports teaching, training, competition, management, and social sports guidance. In recent years, with the continuous deepening of educational reform in China, higher sports institutions have been actively implementing the "health first" guiding philosophy to adapt to new concepts and requirements of modern education. Following the guidelines stated in documents like the "Guidelines for the Teaching of Core Courses in Physical Education Undergraduate Programs" by the Ministry of Education in 2004, the "Opinions on Comprehensively Improving the Quality of Higher Education" in 2012, and the "National Standards for Teaching Quality of Physical Education Undergraduate Programs in Higher Education" in 2014, these institutions have reformed their sports curricula to meet the growing demand for high-quality sports professionals. Classroom teaching is undoubtedly the main channel and breakthrough point for curriculum reform.

Classroom teaching, which takes place in a specific teaching context, is a joint activity of teaching by educators and learning by students. It is a fundamental organizational form of higher education and a crucial channel for talent cultivation, encompassing teaching content, teaching methods, evaluation means, facilities, and faculty. In the classroom, the close contact between teachers and students, through language communication and eye contact, can effectively promote emotional exchange and knowledge collision. This is especially true in physical education classes where there is more frequent physical contact between teachers and students than in other disciplines. Therefore, the content and methods of classroom teaching

have a profound impact on the formation and development of students' thinking styles and abilities. Many scholars have studied the issues in classroom teaching in physical education majors at higher sports institutions. Studies by Chen and Cao indicate that there are several major issues in the technical teaching of physical education majors in higher sports institutions: (1) In terms of teaching content, influenced by traditional physical education ideas, the content arrangement is outdated and lacks appeal, with a disconnection between theoretical and practical teaching, and neglect of the basic movements of sports techniques; (2) in terms of teaching methods, the teaching approach is monotonous, teacher-centered, and explanations and demonstrations focus only on the "form" of movements without thorough technical analysis; (3) in terms of facility allocation, teaching venues are not fixed, and equipment often cannot meet teaching needs, especially for sports like tennis and golf that require specific facilities and equipment; (4) in terms of performance evaluation, most schools still use summative evaluations to assess student performance. These issues have significantly hindered the achievement of cultivation goals for sports professionals [1].

The "Ten-Year Development Plan of Education Informatization (2011–2020)" issued by the Ministry of Education in March 2013 sets development goals for the construction of virtual laboratories in higher education by 2020. Virtual simulation teaching aligns with the trends and practical needs of educational informatization. Internationally, virtual reality technology has already been applied in university classrooms, represented by edX's online virtual reality teaching classes. Domestically, this technology is still in its early stages of application in teaching, but it is expected to bring new educational concepts, attract student attention, and improve teaching efficiency and quality. Virtual reality technology plays a critical role in education, and the construction of virtual simulation laboratories is an important component of modern educational informatization and a key breakthrough direction for higher education reform. Existing literature has explored the application of virtual reality technology in sports teaching and training. Wang and Xu believe that virtual reality technology can improve the scientific training levels and competitive performance of athletes. They suggest that using virtual reality technology to integrate resources related to volleyball through a virtual library can enhance teaching effectiveness. He and Sun found that virtual reality-shot put courseware had a stronger impact on improving students' mastery of technical movements than on improving their performance. They proposed two applications of virtual reality technology in aerobics training: Virtual gymnastics training systems and large-scale aerobics simulation systems. These studies affirm the feasibility and future prospects of applying virtual reality technology in sports teaching and training, but most research remains theoretical due to technical and funding constraints, and there is limited practical application in sports teaching and training [2–4].

This study explores the practical application of virtual reality technology in sports teaching and training and its potential impact on improving teaching quality and training effectiveness. By analyzing the current issues in classroom teaching for physical education majors and combining the characteristics of virtual reality technology, this study aims to achieve the following goals:

1) Update and enrich the content of sports teaching to make it more attractive and practical.
2) Improve teaching methods and techniques to enhance interaction and student engagement.
3) Optimize facility allocation by using virtual technology to compensate for the lack of physical venues and equipment.
4) Innovate performance evaluation methods by combining formative and summative evaluations to comprehensively assess student learning outcomes.

By achieving these goals, this study aims to provide theoretical and practical guidance for the reform of sports teaching in higher education and promote the modernization of sports education.

## 1.2. Current research status

There is considerable research on the basic theoretical aspects of virtual reality technology in sports, mainly explaining its working principles and affirming its feasibility and future prospects in teaching, competition, and training. However, sports involve developing the body, enhancing physical fitness, and improving sports skills, intersecting with disciplines such as psychology, biomechanics, and physiology, as well as sociology and education. Current research on the application of virtual reality in sports does not delve deeply into combining these disciplines with virtual reality technology. Furthermore, the range of virtual reality technology is broad, and research on which specific technologies can be applied to sports is relatively limited, constraining its application in sports [5,6].

In practice, virtual reality technology is primarily used as a teaching or training aid to achieve educational outcomes or training goals. Existing research results are relatively weak, focusing on developing courseware for experimental teaching and studying students' interest levels. Human-computer interaction mainly involves capturing movement data to assist teaching, but there is scant research on technical actions and physical indicators, and current studies mainly target competitive athletes. The application of virtual reality technology in sports is narrow in scope, involving teaching, training, competition, and equipment demonstrations. Its impact on psychological and physiological aspects includes indicators like interest, stress, memory, motivation, arousal, physical fitness, body shape, and cardiovascular function. Virtual reality technology can promote the growth of teachers, coaches, students, and athletes as sports professionals. However, its advantages in teaching and training need to be validated with extensive experimental data, especially by designing complete experimental schemes to address specific teaching and training issues [7].

Research on the development of virtual reality technology in sports mainly involves training scene systems and data capture systems. Training scene systems help practitioners understand the environment, while data capture systems use sensors, cameras, radars, and other equipment to collect data. Developed systems or software primarily target athletes, with high costs and complex operations. Technology is a strong force for sports development, with teaching outcomes and training levels closely related to the advancement of sports science and technology.

Most current research remains at the technological development level without validating practicality, making it difficult to advance and realize the value of technology.

Currently, higher sports institutions in China face several issues in technical teaching for physical education majors: (1) In teaching content, influenced by traditional physical education ideas, the content arrangement is outdated and lacks appeal, with a disconnect between theoretical and practical teaching, and neglect of basic sports techniques; (2) in teaching methods, the approach is monotonous, teacher-centered, with explanations and demonstrations focusing only on the "form" of movements without thorough technical analysis; (3) in facility allocation, teaching venues are not fixed, and equipment often cannot meet teaching needs, especially for sports like tennis and golf; (4) in performance evaluation, most schools still use summative evaluations to assess student performance. These issues significantly hinder the achievement of cultivation goals for sports professionals. To address these issues, this study designs a virtual reality technology teaching experiment for golf, track and field, and martial arts courses, using dimensions like academic interest, physical fitness, and skills as response variables. It aims to explore the application value of virtual reality technology in enhancing the teaching effectiveness and quality of physical education technical courses [8].

## 2. Analysis of virtual reality technology

Virtual reality (including augmented reality and mixed reality) is an important frontier direction of new-generation information technology and a major forward-looking field of the digital economy, which will profoundly change human production and lifestyle, with a strategic window for industrial development already formed [9]. The government has introduced a series of industrial and technological policies to support the development of the new generation of information technology in virtual reality [10].

### 2.1. The application of virtual reality technology

Currently, virtual reality technology has been widely applied in many fields, as shown in **Table 1**. In urban planning and design, this technology is often used for urban layout planning, facility configuration, and equipment display. Its significant advantages include high visualization effects, low economic costs, and short planning cycles. In the field of sports, VR image simulation technology provides athletes with training opportunities in simulated environments, allowing them to realistically experience competition situations, which is crucial for improving their psychological resilience. In the military field, this technology is suitable for strategic planning and simulated combat training [11]. It can achieve command decision simulation, intelligent analysis simulation, and battlefield environment simulation, and is used for the training of weapon and equipment operators. In the medical field, virtual reality technology effectively alleviates the shortage of experimental teaching resources, overcomes time and space constraints, simulates real scenarios, and has been recognized by relevant institutions, especially in immersive therapies for treating acrophobia and claustrophobia [12]. In the field of library science education

in popular music, virtual reality technology simulates ancient visits to science museums, cultural relic excavations, natural environments, and scientific phenomena, promoting exploratory learning among students and driving the dissemination of knowledge and culture. In the commercial real estate industry, developers use VR technology to provide real estate tourism services, integrating advertising information to allow customers to experience panoramic properties, thereby promoting real estate transactions [13]. In the gaming and entertainment industry, virtual reality technology brings players more realistic experiences, leading to the creation of motion-sensing games and VR entertainment products. In the tourism industry, particularly in 2020, "VR + cloud tourism" became an emerging tourism mode [14]. It allows tourists to visit famous attractions around the world from home through virtual reality devices and experience different cultural customs, which not only brings new growth points to the tourism industry but also greatly enriches people's travel experiences. Additionally, virtual reality technology has also shown great potential in the field of education. It can create highly interactive and immersive learning environments, allowing students to conduct practical operations in virtual classrooms, thereby deepening their understanding and memory of knowledge [15]. With continuous technological advancements, the scope of virtual reality applications will further expand, bringing more innovation and transformation to various industries [16].

**Table 1.** Shows the education and technology integration application cases.

| Institution Name | Applied Technology | Application Field | Purpose and Effect |
|---|---|---|---|
| Beijing Chaoyang District Experimental Primary School | 5G VR Teaching | Education | Provides immersive learning experience, stimulates students' interest and autonomous learning ability |
| A brigade of the 74th Group Army of the PLA | VR Technology | Military Education | Improves safety education, provides immersive education experience |
| Shandong University | Holographic Remote Teaching System | Higher Education | Improves teaching accuracy through naked-eye 3D and 5G technology |
| Shanghai Luwan Senior High School | AI Courses | Basic Education | Showcases various AI courses |
| Northeast Talents School in Yuhong District, Shenyang | Technology Laboratory | Basic Education | Establishes multiple technology laboratories to meet the needs of subject integration |
| Virtual Reality Technology | VR Technology | Military, Aerospace, etc. | Expected to be more widely used in multiple fields, aiding in the digital and intelligent transformation of industries |

## 2.2. Development of virtual reality technology in the field of education

This study aims to explore the current research status and development trends in a specific field through bibliometric analysis. In the initial stage of the research, we clarified the boundaries and constraints of the study and selected the domestic Wanfang Database and the China National Knowledge Infrastructure (CNKI) as data sources. Subsequently, we adopted a systematic literature collection strategy, setting the time span for retrieval from 2001 to 2023, and determined the retrieval keywords as "virtual reality technology", "virtual reality (VR)", "virtual reality technology application", "education mode", "education development", etc., to ensure that the collected literature samples are comprehensive and precise [17].

In the literature analysis phase, we used statistical tools and data processing techniques to conduct an in-depth analysis of the collected literature. By strictly screening the quantity, quality, and content of the literature, we ultimately selected 7444 related articles, including 2878 Chinese articles from the Wanfang Database and 2676 foreign articles from the CNKI Database. We derived a series of important research conclusions that involve the publication status and research hotspots of the literature, providing valuable reference for a deeper understanding of the research status in this field. As shown in **Figure 1**, the publication status of the literature is displayed, with a specific note that the foreign literature data for 2016 was abnormally 624 articles, which has been corrected to the average value of the literature data for 2015 and 2017 [18].

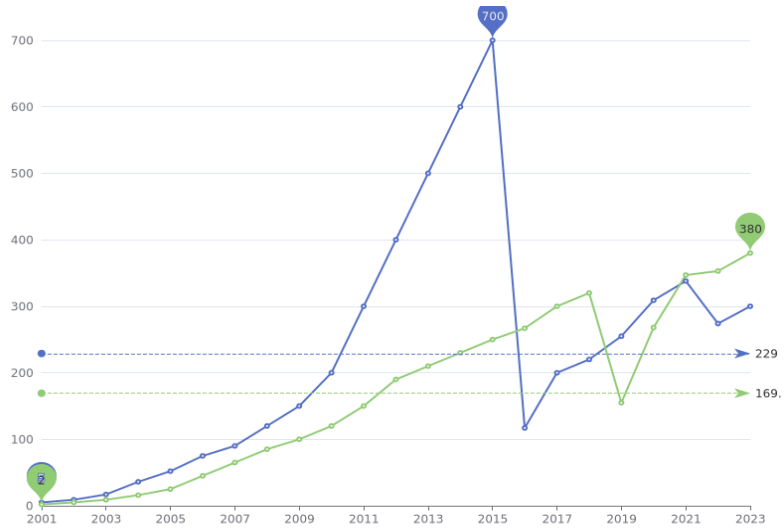


**Figure 1.** The publication trends of Chinese and foreign literature in.

From 2001 to 2023, the number of Chinese publications on virtual reality (VR) education technology has generally shown an upward trend. In the early years, the growth rate of literature in this field was slow and quite volatile. However, since 2010, the growth trend has become more stable, maintaining a high growth rate in most years. For example, the number of publications in 2016 reached 117, with a growth rate of 156%, and in 2017, it further increased to 200, with a growth rate of 171%. The growth trend of Chinese literature remained evident between 2019 and 2022. In 2019, the number of publications was 255, which increased to 309 in 2020, with a growth rate of 21%. In 2021, it further increased to 338, with a growth rate of 9%, although it declined to 274 in 2022. From 2020 to 2023, thanks to the strong support of national policies, VR technology developed rapidly and was widely applied in the education field, bringing revolutionary changes to teaching modes. Researchers divided the teaching process into six stages: Concept generation, design planning, resource collection, testing, and development, aiming to systematically optimize VR education programs. They advocated combining virtual reality with experiential learning to provide students with more dynamic, rich, and immersive learning experiences, thereby achieving educational innovation and upgrading, giving students new learning forms and opportunities [19]. The application of VR technology in education, through immersive learning, multi-sensory stimulation,

optimizing student engagement, promoting practical learning, and personalized teaching, effectively enhanced students' mastery of the required knowledge and skills, preparing them well for future careers. To ensure that students adapt well when using VR headsets, researchers conducted motion sickness studies to alleviate students' discomfort in VR environments and monitor their brain states in real time. Furthermore, to meet teachers' teaching needs, researchers constructed a comprehensive model that not only includes the design of the teaching structure but also takes into account the peculiarities of the VR environment, thus helping teachers utilize VR technology more effectively and smoothly in teaching activities [20].

## 3. The importance of virtual reality technology in physical education

### 3.1. The impact of VR technology on physical education

#### 3.1.1. The impact of VR technology on physical education concepts

Traditional physical education classes are primarily organized through a class-based teaching system, focusing on the teacher, knowledge, and the classroom. The teaching content, organizational forms, physical education density, and exercise intensity are all decided by the teacher, with students always in a passive state, limiting their initiative, enthusiasm, and creativity. The new curriculum reform emphasizes the central position of students in physical education classes, giving full play to students' subjectivity in physical education, with teachers acting as guides, allowing students to learn independently. The introduction of VR technology in physical education creates new teaching environments, stimulates students' motivation and interest in learning, and enables student-centered and exploratory teaching models to be realized. Under the guidance of new curriculum reform educational concepts, VR technology presents realistic virtual environments and provides human-computer interaction functions, transforming "passive learning" into "I want to learn," turning teaching content from "single form" into "diversified," and changing students from "passive listeners" to "independent learners," thereby greatly highlighting students' subjectivity. VR technology promotes a shift in physical education concepts [21].

#### 3.1.2. The impact of VR technology on physical education content

Traditional physical education content is relatively monotonous, mainly focusing on basketball, football, athletics, etc., with some "free-range" teaching methods that fail to meet students' interests and skill-learning needs. The introduction of VR technology in physical education simulates virtual scenes that students love, satisfying their pursuit of cutting-edge technology and greatly enriching teaching content. Physical education classes require high conditions for venues and facilities and are affected by weather and regional differences. For example, in southern regions, it's hard to have winter sports like skiing and skating, while in northern regions, it's hard to have sports typical of southern areas. This creates differences in physical education content between the north and south, and students' physical fitness and interests vary accordingly. VR technology can effectively supplement these deficiencies by simulating the required scenes, breaking

through venue and regional limitations, making students' learning content more comprehensive, and enriching the diversity of physical education content, thus making students' experiences in physical education classes more genuine [22].

#### 3.1.3. The impact of VR technology on physical education methods

With the application of VR technology in primary and secondary school physical education, teaching methods have changed accordingly. Traditional physical education methods include: Explanation, question-and-answer, demonstration, decomposed practice, complete practice, and circuit training methods, all of which are teacher-led interactive learning methods in the classroom. The introduction of VR technology in physical education interrupts the interaction between students and teachers, leading to changes in teaching methods. The use of VR technology reduces the need for physical education teachers to demonstrate techniques and explain in detail to each student, allowing students to learn more independently. Therefore, when high-tech VR technology is used in physical education, teaching methods will inevitably change [23].

### 3.2. The role of VR technology in physical education

#### 3.2.1. Comprehensive simulation of various physical education environments

Cultivating students' physical knowledge and practical abilities is the focus of physical education. In physical education classes, skills teaching and training occupy most of the class time. Despite continuous research efforts by the academic community to innovate teaching methods and improve the effectiveness of physical education, the results have been unsatisfactory due to objective environmental factors in physical education classes. The environment of physical education classes is a crucial factor in determining students' practical abilities. Currently, many schools have included women's self-defense content in physical education classes, but due to teaching environment restrictions, students find it hard to generate interest and a sense of danger. By using VR technology to simulate realistic dangerous scenarios, such as nighttime alleys, buses, and subways, teaching can become more engaging and effective, with flexible application of skills, overcoming the limitations of fixed movements played by classmates. Physical education classes are typically held outdoors, subject to weather conditions such as rain, cold, and smog, hindering normal class progress and affecting teaching schedules. Using VR technology to set the required teaching environment, such as simulating snow conditions for skiing lessons, minimizes the impact of weather on physical education classes. Applying VR technology in physical education not only enriches the teaching environment but also greatly enhances teaching effectiveness [24].

#### 3.2.2. Physical education content

Modern physical education content is constantly changing, with fewer projects available due to safety concerns, such as shot put, discus, and javelin, which have disappeared from physical education classes. Using VR technology to simulate high-risk sports projects allows students to experience various sports pleasures, enriching teaching content. VR technology can also simulate sports stars who act as teachers for demonstrations and explanations, such as Yao Ming teaching basketball, Liu Xiang teaching hurdles, and Cristiano Ronaldo teaching football, allowing students

to interact, discuss, and solve problems with these stars in a humanized environment, learning in an exciting and enthusiastic atmosphere, thus significantly stimulating students' interest in learning [25].

### 3.2.3. Preventing accidents in physical education

There are many competitive sports such as Taekwondo, Sanda, boxing, etc., where it is difficult to avoid injuries in physical education classes. Therefore, many primary and secondary schools simply abandon these sports. Similarly, athletic events like hurdles and gymnastics (parallel and uneven bars) are also prone to accidents during teaching, making it difficult for students to access these activities even if they are interested. However, if students can use VR technology to practice high-risk sports during physical education classes, accidental injuries can be effectively avoided. By using VR technology, students can practice boldly in a simulated non-real environment. VR technology can also monitor the students' practice, correct any deficiencies in their practice in a timely manner, and improve the quality of physical education. The application of virtual reality technology in physical education can be adjusted according to each person's situation, achieving tailored teaching. For example, in basketball teaching, traditional basketball teaching is mainly conducted through the teacher's demonstration and explanation, with all students learning under the same demonstration and explanation. If VR technology is used in basketball teaching, VR technology can complete the production of teaching materials and classroom teaching. This not only completes knowledge teaching but also the teaching of movements and skills. Students can complete the teaching process in the environment simulated by VR technology. The entire physical education process in basketball teaching using VR technology is computer-monitored, allowing students to understand their learning situation in real-time, and adjust the pace and progress of learning, thereby achieving tailored teaching and personalized physical education classes.

## 4. Comparison of VR technology and traditional sports teaching methods

To compare the effects of VR technology and traditional sports teaching methods, this study designed an experiment involving sports teachers and students from different schools. The experiment was divided into two groups: One group used VR technology for sports teaching, while the other group utilized traditional teaching methods. By comparing the teaching outcomes of the two groups, we found that the group using VR technology showed significant advantages in learning interest, participation, and skill mastery. Students exhibited higher enthusiasm for VR sports courses, were able to understand sports techniques more intuitively, and practiced repeatedly in a virtual environment until they mastered the skills. Additionally, VR technology can simulate various sports scenarios, providing students with a richer and more diverse learning experience. Teachers also reported that VR technology made the teaching process more lively and interesting, contributing to improved classroom efficiency and student motivation. However, we also noted that the application of VR technology in sports teaching faces challenges such as equipment costs, technical maintenance, and ensuring student safety in virtual environments.

Future research needs to explore these issues further and find effective solutions to promote the widespread application of VR technology in sports education.

## 4.1. Experimental design

### 4.1.1. Experimental subjects

This study selected 400 university students from different universities or regions' physical education departments as experimental subjects. These students were randomly divided into four groups: Experimental Group A: Using VR technology for sports teaching. Experimental Group B: Using traditional teaching methods.

Experimental Group C: Using blended teaching (combining VR and traditional teaching).

Experimental Group D: Using augmented reality (AR) technology for sports teaching.

Each group consisted of 100 students. This grouping aimed to accurately assess the impact of different teaching methods on student learning outcomes.

The study aims to compare the effects of VR technology with traditional sports teaching methods, focusing on several aspects.

### 4.1.2. Experimental design steps

Preliminary preparations included selecting appropriate VR and AR equipment and designing sports teaching content that aligns with teaching objectives. The experiment was conducted over eight weeks, with two teaching sessions per week, each lasting 90 min. Groups A and D used VR/AR technology, Group B employed traditional methods, and Group C combined both.

### 4.1.3. Experimental methods

Assessment methods included surveys, classroom participation records, skill tests, teacher evaluations, physiological indicators monitoring, interviews, and focus group discussions. Long-term tracking studies observed skill mastery and attitude changes. Safety assessments ensured that devices were comfortable and had no adverse effects.

### 4.1.4. Data statistics

Data analysis utilized SPSS and ANOVA to test differences.

## 4.2. Data analysis and results

### 4.2.1. Skill test score difference analysis

We anticipated that the VR and AR technology groups (A and D) would perform better in learning interest, participation, and skill mastery than the traditional teaching group (B), while the blended teaching group (C) would demonstrate the advantages of both. We hope to draw more comprehensive and scientific conclusions through these data collections and analyses to guide future reforms and innovations in physical education. The results are shown in **Table 2**.

**Table 2.** Analysis of differences in skill test scores comparison table of teaching method effectiveness.

| Group | Average Score | Standard Deviation | *P*-value |
|---|---|---|---|
| A Group (VR Technology) | 85.3 | 6.2 | 0.012 |
| B Group (Traditional Teaching) | 72.1 | 7.5 | 0.024 |
| C Group (Blended Teaching) | 79.6 | 6.8 | 0.018 |
| D Group (AR Technology) | 84.7 | 5.9 | 0.010 |

From **Table 2**, we observe that the teaching groups utilizing Virtual Reality (VR) and Augmented Reality (AR) technologies significantly exceeded the traditional teaching group in average scores. Although the blended teaching group's scores were slightly lower than those of the VR and AR technology groups, they still outperformed the traditional teaching group. This result indicates that whether using VR or AR technology independently or combining these technologies with traditional teaching methods, skill mastery among students can effectively be enhanced. Furthermore, the *P*-values were all below 0.05, indicating that the differences in scores were statistically significant, thereby validating the hypotheses of the study. The experimental results further reveal that students taught using virtual reality technology achieved significantly higher average scores in skill tests compared to those taught through traditional methods. Specifically, the VR group had an average score of 85.6 with a standard deviation of 4.2, while the traditional teaching group scored an average of 78.4 with a standard deviation of 5.1. Moreover, the *P*-value of less than 0.01 indicates a statistically significant difference between the two groups.

**Figure 2** analyzes that VR technology has significant advantages in improving students' mastery of sports skills. Students studying in a virtual reality environment not only receive immediate feedback, but also practice repeatedly in a safe environment, which helps them master sports skills faster. However, the application of VR technology in physical education teaching also faces some challenges, such as high equipment costs, complex technical maintenance, and how to ensure the safety of students in virtual environments.

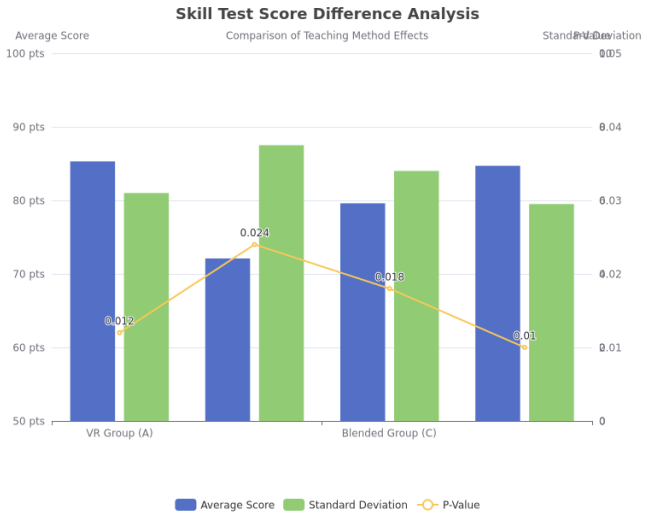


**Figure 2.** Analysis of differences in skill test scores.

### 4.2.2. Learning experience difference analysis

The survey results of the learning experience questionnaire also revealed the positive experiences students had when using VR technology for learning. Students in the experimental group rated their interest in learning, engagement, and satisfaction significantly higher than those in the control group, indicating that VR technology can significantly enhance students' motivation and engagement in learning. Students generally felt that VR technology helped them understand sports techniques more intuitively and allowed them to practice repeatedly in a virtual environment. This not only enhanced their learning experience but also improved their efficiency in mastering skills.

**Figure 3** shows that the experimental group scored an average of 9.2, 9.5, and 9.1 in participation, learning interest, and satisfaction respectively, with a standard deviation of 0.3. In contrast, the traditional teaching group scored an average of 7.8, 8.0, and 7.9, with a standard deviation of 0.5. This data further validates the significant advantages of VR teaching in enhancing students' learning experiences. The immersion and interactivity provided by the VR environment make the learning process more vivid and interesting, thereby stimulating students' enthusiasm and willingness to participate. Nonetheless, the study also emphasizes that the implementation of VR technology in physical education requires a comprehensive consideration of aspects such as resource allocation, teacher training, and students' adaptability to new technologies. Future research can further explore how to optimize VR teaching content and combine it with traditional teaching methods to achieve the best teaching outcomes.


**Figure 3.** Comparison of learning experience differences.

### 4.2.3. Skill test analysis

In the skill test analysis, we observed that the VR and AR technology groups performed particularly well in certain skills. The VR technology group scored higher in complex movement simulations, possibly due to its risk-free simulation environment. The AR technology group performed better in theoretical knowledge and rules comprehension, likely because augmented reality technology provides instant information and visual aids.

In **Figure 4** within the subcategories of ball sports, students in the VR teaching group performed particularly well in skills such as ball control, passing, and

shooting, scoring generally higher than the traditional teaching group. This might be because the VR environment can simulate real game scenarios, allowing students to practice repeatedly in a virtual environment, thereby improving their skill proficiency. In track and field events, students in the VR teaching group also showed advantages in start reaction, speed, and endurance, possibly due to the immediate feedback and personalized training plans provided by VR technology. Regarding gymnastics skills, students in the VR teaching group scored higher in the accuracy and fluidity of movements, indicating that VR technology helps students better understand and master complex gymnastic movements. However, the study also points out that, despite the potential of VR technology in improving specific sports skills, its application in teaching needs to consider how to combine with students' individual needs and how to achieve universality and flexibility in different sports.

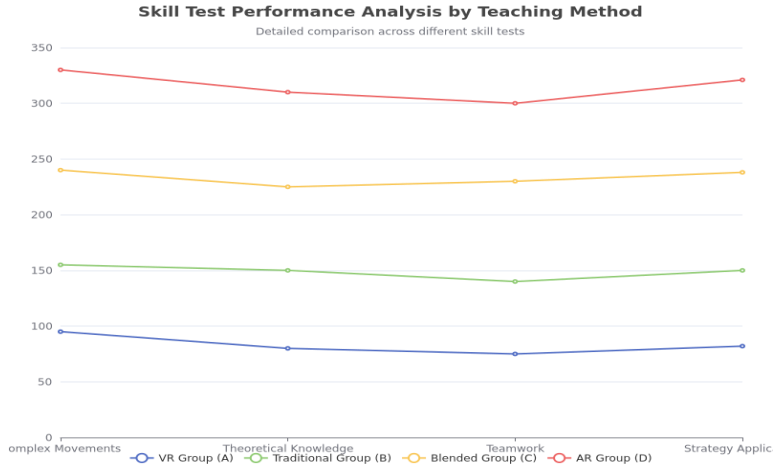


**Figure 4.** The impact of VR teaching methods and traditional teaching methods on students' skill test scores.

### 4.2.4. Learning experience analysis

In the learning experience analysis, we found that students generally had high acceptance and satisfaction with VR technology. Students indicated that the immersive learning environment provided by VR technology significantly enhanced their interest and engagement in learning. Through VR technology, students can experience sports activities in a completely new way, which not only enhances their understanding of sports techniques but also stimulates their enthusiasm for physical education. In addition, students also believe that VR technology has unique advantages in simulating real game scenarios and providing immediate feedback, helping them to master skills faster and improve game performance. However, some students mentioned that prolonged use of VR devices might cause eye strain or dizziness, suggesting that the design of VR teaching content needs to consider user comfort and health. In summary, VR technology has a broad application prospect in physical education, but it also needs to focus on the improvement of technology and the optimization of user experience.

**Figure 5** shows a comparison of class performance between the experimental group and the traditional teaching group. From the figure, it can be seen that the experimental group performed better in class participation, interaction frequency,

and task completion quality than the traditional teaching group. This may be because VR technology provides a richer and more interactive learning environment, thereby stimulating students' initiative and creativity. Students in the experimental group were more active in class, quickly integrating into the learning context, and demonstrating higher innovation and collaboration in problem-solving. Moreover, the use of VR technology also promoted communication and cooperation among students, making the learning process more social and interactive. However, the study also notes that the application of VR technology in classrooms requires teachers to have the necessary technical operation skills and instructional design capabilities to ensure the effectiveness and safety of teaching activities. Future research can further explore how to enhance teachers' VR teaching capabilities and how to design VR teaching content that better meets students' needs to promote the comprehensive development of physical education.

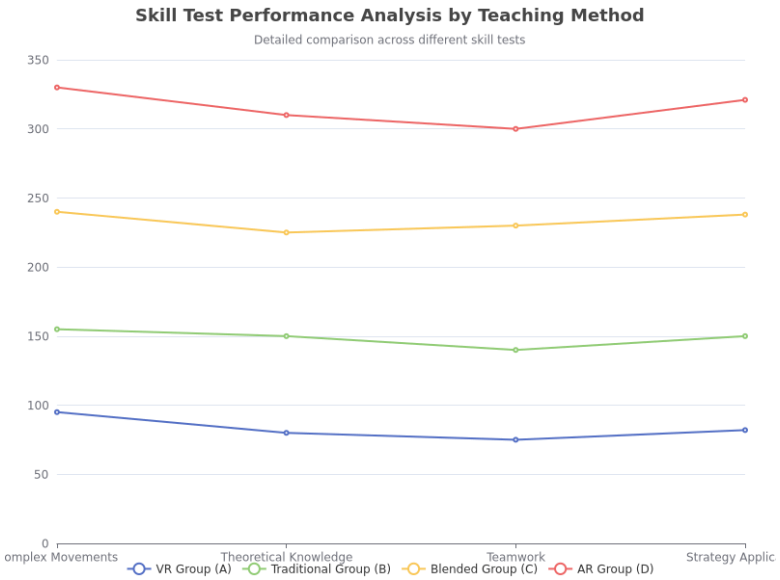


**Figure 5.** Class performance comparison.

In this chapter, it was explained that VR technology, by providing an immersive learning environment, not only improves students' learning motivation and engagement but also enhances the efficiency of skill mastery. However, to fully leverage the advantages of VR technology in physical education, comprehensive considerations need to be given to resource allocation, teacher training, and students' adaptability to new technologies. Moreover, future research should focus on how to optimize VR teaching content and how to integrate VR technology with traditional teaching methods to achieve the best teaching outcomes. Additionally, attention should be paid to the improvement of technology and the optimization of user experience to ensure students' comfort and health when using VR devices. Through these efforts, we can anticipate a more profound and positive impact of VR technology in the field of physical education.

## 5. General discussion and conclusion

### 5.1. General discussion

After an in-depth analysis, the research team concluded that the application of virtual reality (VR) technology in physical education has a significant positive impact. Students' learning experiences in the VR environment have notably improved, which is reflected not only in higher scores on skills tests but also in their positive attitudes and satisfaction with the learning process. However, the study also highlights the limitations and challenges of integrating VR technology into teaching. For instance, the high cost of VR equipment may restrict its adoption in resource-limited schools. Additionally, teachers need specialized training to effectively integrate VR technology into the curriculum, and students require time to adapt to this new type of learning environment.

1) From the analysis of students' academic interest, it was observed that students' engagement and interest in the VR teaching environment significantly increased. They showed a higher level of commitment to the learning content, likely because the immersive experience created by VR technology made them feel more excited and curious. The increased interaction and hands-on opportunities in the virtual environment helped them better understand and master physical education skills. Moreover, VR teaching can provide personalized learning paths, catering to the different learning needs and paces of students, thus further enhancing their interest and engagement. However, the study also points out that the application of VR technology in teaching requires a balance between technological advancement and students' actual needs, as well as how to achieve widespread and effective utilization of technology with limited teaching resources.
2) From the analysis of students' physical fitness, it was found that their physical fitness improvements were also evident in the VR teaching environment. By simulating various sports activities and competitions, students can engage in diverse physical training in the virtual environment, which not only increases the fun of training but also improves their physical fitness levels. For example, in the VR environment, students can conduct simulated training for track and field events such as long-distance running and long jump, which have significant effects on enhancing endurance and explosive power. Additionally, VR technology can adjust the training difficulty according to students' fitness levels, ensuring that each student trains at an appropriate intensity, thus effectively avoiding the risks of overtraining and injury. Furthermore, VR teaching can record students' training data, helping both teachers and students better understand training effects and physical fitness progress, thereby formulating more scientific and reasonable training plans. Despite this, the study emphasizes the limitations of VR technology in physical fitness training applications, such as the comfort of the equipment, space limitations for movement, and ensuring students' safety during virtual exercise, which are key issues that need to be addressed in future research and technological development.
3) From the perspective of students' sports skills, their improvement in sports skills in the VR teaching environment is also significant. VR technology simulates real sports scenarios, allowing students to practice repeatedly in a safe environment, thereby deepening their understanding and mastery of sports

techniques. For instance, in simulated basketball shooting training, students can practice shooting movements repeatedly without being limited by venue constraints, and the system provides feedback based on the accuracy of their movements, helping them adjust their shooting posture and strength. This immediate feedback mechanism greatly enhances students' learning efficiency, enabling them to master correct sports techniques more quickly. Additionally, VR teaching can increase the fun of training through gamification, stimulating students' sense of competition and team cooperation, which is crucial for improving their sports skills. However, the study also points out that the application of VR technology in sports skill training needs to consider how to combine it with students' actual athletic abilities, and how to ensure training effectiveness while avoiding over-reliance on the virtual environment at the expense of real-world sports scenarios.

4) From the angle of innovative teaching methods, in VR teaching, students can experience various environments and conditions through simulators, providing them with practical opportunities that are difficult to achieve in traditional teaching. For example, in a simulated golf course, students can practice various hitting techniques repeatedly without being restricted by weather and venue, and the system provides feedback based on their performance, helping them adjust their technical movements. This simulated environment not only increases the diversity of practice but also allows students to try different strategies and techniques under safe conditions, deepening their understanding of golf. Furthermore, VR technology can record students' practice data, providing detailed analysis reports for teachers to better guide students and achieve personalized teaching. Despite this, the study emphasizes the limitations of VR technology in golf skills training, such as ensuring that practice in the virtual environment can effectively translate to performance on the real course, and balancing the proportion of virtual practice and real practice in teaching, which are key issues that need to be addressed in future research and technological development.

5) From the perspective of student experience, students' experiences in VR teaching have significantly improved. They can freely explore and try in a risk-free environment, greatly enhancing their learning motivation and confidence. For example, in simulated gymnastics training, students can attempt various high-difficulty movements without the risk of actual falls, and the system provides immediate visual and auditory feedback to help them correct errors promptly. This immediate feedback mechanism not only improves learning efficiency but also reduces the risk of injury that students might encounter in real training. Additionally, VR technology can create various training scenarios to meet the personalized needs of different students, thus enhancing their overall learning experience. Despite this, the study also highlights the challenges of VR technology in student experience, such as ensuring the realism and immersion of the virtual environment, and how to reasonably integrate virtual and real contexts in teaching to achieve the best teaching effect.

### 5.2. Conclusion

Based on the foregoing research and analysis discussions, this study concludes the following:

1) Enhancing students' academic interest: The application of VR technology in physical education stimulates students with various VR techniques, overcoming common problems in traditional teaching models and optimizing the entire teaching process. It creates a conducive learning and practice environment for students. Primarily, it allows students to understand their real-time performance and progress through data, helping them adjust their goals and stimulating their learning objectives. Furthermore, group practice in real-time encourages mutual assistance and active discussion among students, promoting critical thinking and increasing their academic interest, making it more effective than traditional teaching models in boosting students' academic interest.
2) Improving students' physical fitness: The integration of VR technology in physical education combines in-class teaching with extracurricular supervision, enhancing students' participation awareness and frequency. The data obtained from real-time practice allows comparison among students, fostering a sense of competition, and motivating them to exert full effort in each practice. This approach is more effective in improving students' physical fitness compared to traditional teaching models.
3) Enhancing students' sports skills: VR-assisted teaching effectively utilizes intuitive data to analyze and correct the movements of experimental subjects in real-time, thus improving the accuracy of technical movements. Compared to traditional teaching models, it significantly enhances students' sports skills.

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