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Research article

Development of a Virtual Reality for Physiology Education

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Abstract: This study explores the development and evaluation of a Virtual Reality (VR)-based Massive Open Online Course (MOOC) designed to enhance the learning of complex physiological concepts in exercise physiology education. Traditional teaching methods often struggle to effectively convey dynamic physiological processes, such as muscle contraction and energy metabolism. By utilizing VR technology, this research provides an immersive, interactive environment for students to visualize and engage with these processes in 3D. The study employed a Research and Development (R&D) approach, using the 4D model (Define, Design, Development, Dissemination) to create and assess the VR program. Experts in physiology, educational media, and linguistics validated the content, ensuring both pedagogical soundness and technical quality. Evaluation methods included expert validation questionnaires, practicality surveys, and student feedback. The tool received high ratings for its educational value, interactivity, and usability, with an average expert validation score of 97.42% and a student practicality score of 98.89%. Instructors found the VR program practical for enhancing conceptual learning, especially in visualizing complex processes difficult to simulate in traditional settings. The study suggests that integrating VR with MOOCs can democratize access to exercise physiology education globally. However, challenges related to technology access and content development remain. Future research should explore VR's long-term impact on knowledge retention and its applicability in real-world scenarios. This research demonstrates VR's potential to revolutionize specialized education by offering scalable, immersive, and engaging learning experiences that enhance both accessibility and effectiveness.

Keywords: Virtual Reality (VR),Exercise Physiology, MOOCs, Immersive Learning, Educational Technology

1. Introduction

Virtual Reality (VR) technology, once a futuristic concept, has now become an integral part of various industries, from gaming to healthcare, and its potential to revolutionize education is particularly noteworthy [1], [2], [3] [4], [5]. In recent years, VR has demonstrated significant promise as an immersive tool that enables users to interact with dynamic, three-dimensional environments [6], [7], [8], [9]. Through a head-mounted display and motion-tracking sensors, VR creates a sense of presence, where users are no longer passive recipients of information but active participants in a simulated world [10]. This technology's ability to simulate real-world scenarios with high levels of interactivity offers a range of applications across different fields of learning, including exercise physiology education [11]. Exercise physiology, a discipline that studies the body's responses to physical activity, relies heavily on understanding complex physiological processes, such as muscle contraction, energy metabolism, and cardiovascular adaptations during exercise [12]. These concepts, often abstract and difficult to conceptualize for students, are typically taught through textbooks, diagrams, and lecture-based instruction. While these traditional methods serve their purpose,

they fail to provide an experiential learning environment that allows students to explore and interact with the physiological systems they are studying [13], [14], [15]. This is where VR technology can play a transformative role. By creating fully immersive, interactive simulations, VR provides a hands-on approach that enhances student engagement and fosters a deeper understanding of exercise physiology concepts.

The integration of VR into educational frameworks, especially Massive Open Online Courses (MOOCs), has the potential to democratize learning by offering scalable and flexible access to high-quality educational resources [16]. MOOCs, which have already redefined the landscape of online learning, offer open access to educational content, allowing learners from diverse backgrounds to engage with academic material that might otherwise be inaccessible due to geographical or institutional constraints. The combination of VR technology with MOOCs can further enhance this experience by offering virtual labs, real-time physiological simulations, and performance-based assessments that are often impractical or impossible in traditional, non-virtual settings. One of the core advantages of VR in exercise physiology education is its ability to present abstract concepts in a visually engaging and interactive manner. For instance, rather than reading about muscle contraction or energy expenditure, students can virtually "experience" these processes. VR enables learners to explore the physiological systems of the human body in 3D, gaining a better understanding of how muscles, tissues, and organs interact during exercise. A virtual simulation could allow students to see how muscle fibers contract, how lactic acid builds up during anaerobic exercise, or how the heart rate increases in response to physical exertion. These visual and tactile experiences bridge the gap between theoretical knowledge and practical understanding, helping students to grasp otherwise complex and difficult-to-understand content.

Additionally, VR has been shown to improve learner motivation and engagement, which is crucial in the context of exercise physiology education. Traditional learning models, such as lectures and textbook readings, often fail to capture students' attention, leading to passive learning and, at times, disengagement. VR, by contrast, offers a novel and exciting learning environment that can increase motivation by tapping into students' curiosity and desire for hands-on experiences. When students are immersed in a virtual environment where they can actively interact with the material and see the immediate effects of their actions, they are more likely to retain and apply the knowledge. Moreover, VR simulations allow for repetition without the limitations of time, resources, or the need for physical space. Students can revisit specific physiological processes as often as needed, reinforcing learning through active participation. When integrated into a MOOC platform, VR can provide accessible, flexible, and scalable opportunities for students to engage with exercise physiology content, irrespective of their geographical location, prior experience, or institutional affiliation. MOOCs are known for their ability to reach a large number of learners across the world, making education accessible to people who may not have otherwise had the chance to engage with a specialized field such as exercise physiology. Virtual reality modules within these platforms can further enhance the learning experience by offering simulations of exercise testing, human performance metrics, and real-time physiological data collection—all critical components of exercise physiology education. Students can practice interpreting results from these virtual exercises, applying theoretical knowledge to real-world scenarios, and receiving instant feedback on their performance.

A VR-based MOOC in exercise physiology would not only benefit students by providing rich, interactive content, but also offer educators new ways to assess students' understanding. Traditional assessment methods, such as written exams or quizzes, are limited in their ability to measure students' conceptual grasp in practical, real-world scenarios. VR-based assessments, on the other hand, allow students to apply their knowledge in dynamic, immersive environments. For example, a student could be tasked with interpreting a virtual exercise test, identifying whether a subject's heart rate and oxygen consumption levels are within expected ranges, and diagnosing potential issues. These assessments would be more reflective of real-world skills, such as critical

thinking, problem-solving, and data interpretation, providing a more comprehensive evaluation of students' learning outcomes.

The development of a VR-based MOOC in exercise physiology, however, presents several challenges. Creating high-quality, pedagogically sound VR content requires collaboration between subject matter experts, instructional designers, and VR developers. The technology itself needs to be carefully selected to ensure compatibility with various devices, while the content must be designed to engage learners and meet educational objectives effectively. Additionally, the integration of VR with assessment tools must align with the intended learning outcomes and ensure that students can be fairly and accurately evaluated based on their understanding of complex physiological concepts. The incorporation of VR technology into exercise physiology education has the potential to transform the way students engage with and understand the subject. By providing interactive, immersive learning experiences through VR-based MOOCs, learners can gain a deeper, more practical understanding of physiological processes, while enjoying increased motivation and engagement. As technology continues to evolve, the integration of VR into educational platforms will likely become a key factor in enhancing both the accessibility and effectiveness of learning in specialized fields like exercise physiology.

2. Materials and methods

This study employed a Research and Development (R&D) approach to develop a Virtual Reality (VR) program for physiology education aimed at enhancing students' understanding of complex physiological concepts. The development followed the 4D model: Define, Design, Development, and Dissemination. Participants included experts in physiology, educational media, and linguistics for validation, as well as a pilot group of 10 undergraduate students to assess usability and practicality. In the Define stage, researchers identified learning objectives, student needs, and difficulties in understanding abstract physiological processes. In Design, the VR program was conceptualized with interactive simulations, virtual labs, and intuitive user interfaces tailored for student engagement. During Development, the program was created, integrated, and tested with both experts and students. The Dissemination stage involved introducing the program to a wider audience and preparing it for academic and educational use. Instruments included an application assessment questionnaire for expert validation and a practicality questionnaire for students. Validity was evaluated using Aiken's V, yielding 0.86 (high validity), while practicality was analyzed descriptively with a percentage score. This methodology ensured that the VR program was systematically developed, validated, and practically in physiology education. The following rating scale was used for both expert validation and practicality assessment. Scores range from 1 to 5, where higher scores indicate better quality or higher practicality. The categories correspond to descriptive labels to facilitate interpretation of results. For more details, see Table 1.

Table 1. Rating Scale for Validation and Practicality

Score	Category
1	Bad / Not Practical
2	Not Good / Less Practical
3	Moderate / Fair
4	Good / Practical
5	Very Good / Very Practical

Experts in media and exercise physiology evaluated the VR application using specific indicators related to both technical and content aspects. Media experts assessed visual, navigational, and linguistic features, while material experts evaluated content accuracy, relevance, and clarity. For more details, see Table 2.

Table 2. Expert Validation Questionnaire (Media and Material)

Aspect	Indicators
Media	Visual suitability and clarity
	Ease of navigation
	Animation quality and interactivity
	Design consistency
	Appropriateness of language
Material	Relevance to exercise physiology material
	Accuracy of physiological concepts
	Appropriateness of content depth for students
	Clarity of content presentation
	Language readability and suitability

The practicality of the VR application was evaluated by instructors and students. Instructors assessed ease of integration into lectures, operational feasibility, and pedagogical effectiveness, while students evaluated usability, engagement, and learning benefits. For more details, see Table 3.

Table 3. Practicality Questionnaire (Instructors and Students)

Respondent	Indicators
Instructors	Ease of integrating VR into lectures
	Ease of operation and accessibility
	Relevance to learning objectives
	Clarity of instructions and interface
	Effectiveness in supporting understanding of complex concepts
Students	Ease of use and navigation
	Clarity of information presentation
	Level of engagement and motivation
	Helpfulness in understanding physiological concepts
	Suitability as an independent and interactive learning tool

3. Results

Define

In the initial phase of this study, data collection was conducted through a comprehensive literature review and field observations in exercise physiology education settings. A survey was also distributed to instructors and curriculum developers in sports science departments to understand the current use of educational technology and digital platforms, particularly in large-scale or online learning environments. The findings indicated that while interest in technology-enhanced learning is growing, the integration of Virtual Reality (VR)—especially for assessing conceptual understanding in exercise physiology—remains limited and underutilized in MOOC settings

Design

The research instruments, including needs analysis questionnaires and expert consultation forms, were carefully designed to ensure validity and reliability. The planning focused on identifying key conceptual areas in exercise physiology (e.g., energy systems, cardiorespiratory adaptations, muscular function) that could benefit from immersive visualization and interactive assessment. This phase also outlined pedagogical strategies to align VR-based modules with MOOC delivery, ensuring accessibility, interactivity, and scalability.

Development

The VR MOOC was developed with the goal of supporting both conceptual learning and formative assessment through immersive experiences. The application design included:

1. Interactive simulations of physiological processes (e.g., blood flow during exercise, muscle fiber recruitment)
2. Quizzes and knowledge checks embedded within the VR environment
3. Scenario-based learning tasks, such as virtual lab experiments and decision-making in exercise prescription

The content was structured into modular units aligned with standard exercise physiology curricula. Students could navigate through the VR environment to explore theoretical concepts, visualize dynamic systems, and receive immediate feedback through interactive assessments. For more details, see Figure 1.

Figure 1. Product VR

Media experts evaluated the application based on technical functionality, visual communication, and language. The average score from media experts was 97.42%, with recommendations to enhance animations for further engagement. For more details, see Table 4.

Table 4. Average Media Expert Validation Results

Aspect	V1	V2	V3	Σ	Cat
Software	100%	100%	100%	100%	Very Good
Visual	89.29%	100%	100%	96.43%	Very Good
Language	100%	100%	87.5%	95.83%	Very Good
Average	96.43%	100%	95.83%	97.42%	Very Good

Subject-matter experts also reviewed the content based on its quality, its relevance to sports physiology material, and its accessibility for sports science students. The material received an average score of 99.24%, indicating that it met the

needs of the target group effectively. Experts suggested incorporating more varied motion examples to better support diverse learning needs. For more details, see Table 5.

Table 5. Average Material Expert Validation Results

Aspect	V1	V2	V3	Σ	Cat
Content	95%	100%	100%	98.33%	Very Good
Serving	100%	95.83%	100%	98.61%	Very Good
Language	100%	100%	100%	100%	Very Good
Average	98.75%	98.96%	100%	99.24%	Very Good

Dissemination

Following validation, the VR-based MOOC was tested for practicality in real classroom settings with instructors teaching exercise physiology at the university level. These instructors evaluated the tool based on its usability, integration into existing course structures, and its ability to support conceptual understanding through immersive learning experiences. The results showed that the VR tool was highly practical, achieving an average score of 98.89%. Instructors noted that the platform was user-friendly, pedagogically relevant, and effectively supported students' comprehension of complex physiological concepts. They also observed that the VR modules could serve as a powerful supplement to traditional lectures and lab sessions, particularly for visualizing abstract or dynamic processes in the human body. For more details, see Table 6.

Table 6. Average Results of Instructor Practicality Test

Aspect	V1	V2	V3	Σ	Cat
Content	100%	100%	91.66%	97.22%	Very Good
Serving	100%	100%	91.66%	97.22%	Very Good
Language	100%	100%	100%	100%	Very Good
Technical Aspects	100%	100%	100%	100%	Very Good
Average	100%	100%	96.66%	98.89%	Very Good

The next phase involved conducting a large-scale trial with 30 undergraduate students enrolled in exercise physiology courses across three different universities. The primary objective was to evaluate the effectiveness of the VR-based MOOC in enhancing students' conceptual understanding and to gather feedback on user experience and engagement.

The results indicated that 96% of students rated the tool as "Very Good" in terms of both educational value and interactivity. This feedback demonstrated that the VR MOOC was highly effective in increasing student motivation, improving comprehension of complex physiological processes, and providing an engaging alternative to conventional learning methods. Students particularly appreciated the immersive simulations, real-time feedback, and the opportunity to visualize abstract concepts in a practical context. For more details, see Table 7.

Table 7. Average Student Response Test Results

No	Interval (%)	F (Frequency)	%	Category
1	81% – 100%	53	96%	Very Good
2	61% – 80%	2	4%	Good
3	41% – 60%	0	0%	Moderate
4	21% – 40%	0	0%	Not Good
5	0% – 20%	0	0%	Bad

4. Discussion

The integration of Virtual Reality (VR) into education, particularly in the field of exercise physiology, is a significant step forward in addressing the challenges of traditional learning models. By offering an immersive and interactive learning environment, VR allows students to visualize and engage with dynamic physiological processes in a more intuitive and meaningful way.

Several studies support the notion that VR can enhance learning, particularly in areas where hands-on or experiential learning is essential. VR enhances students' understanding by providing a deeper engagement with content, especially in subjects that require visualizing processes or phenomena not directly observable in the real world [17]. VR-based learning environments increase students' retention and understanding by allowing them to interact with the content in ways that traditional methods cannot offer [18]. Furthermore, VR environments increase students' motivation and engagement, leading to improved learning outcomes [19]. This supports the findings of the current study, where students demonstrated enhanced understanding and motivation after interacting with the VR-based exercise physiology MOOC.

This research contributes to the growing literature on immersive learning technology in special education. In addition, the combination of VR with MOOC provides an opportunity to democratize access to high-quality education in exercise physiology. Because MOOCs can reach a global audience, the integration of VR can offer learners, regardless of their geographic location or resources, the chance to engage in interactive and practical learning experiences. This is particularly beneficial in fields like exercise physiology, where practical understanding of complex processes is essential for students pursuing careers in health, fitness, or sports science.

However, there are some limitations to consider. One of the primary challenges in VR-based education is the technological infrastructure required. For instance, the development and deployment of VR content require specialized equipment, such as headsets and motion-tracking sensors, which might not be readily available to all students or institutions, particularly in low-resource settings. Additionally, while VR can provide immersive learning experiences, it still requires substantial investment in content creation, which may be resource-intensive for institutions or educators with limited budgets. Furthermore, the efficacy of VR as a learning tool can vary depending on students' prior experience with technology. Some students may find the VR environment disorienting or may struggle to interact with it effectively, which could impact their overall learning experience.

Based on these limitations, several recommendations can be made for future research and development. First, it is crucial to expand the scope of this study to include a more diverse student population, including those with different technological skill levels and educational backgrounds. This would help assess the usability and effectiveness of VR tools in a wider range of contexts. Second, future VR-based learning platforms should focus on improving accessibility by ensuring

compatibility with a broader range of devices, including lower-cost VR headsets and even mobile platforms. This would help overcome the technological barriers and make VR-based education more accessible to a global audience. Additionally, content developers should explore the use of augmented reality (AR) alongside VR to create hybrid learning environments that allow students to interact with both real and virtual elements. This could provide a more seamless integration of theoretical and practical learning experiences.

Finally, it is essential to continue investigating the long-term impacts of VR-based learning. While the current study shows immediate positive effects in terms of engagement and understanding, further research should examine how well these learning outcomes persist over time and how VR-based learning affects students' ability to apply their knowledge in real-world scenarios. Longitudinal studies could help provide a clearer picture of VR's potential in transforming education and its long-term impact on student outcomes. In conclusion, this study highlights the transformative potential of VR in exercise physiology education and its capacity to enhance student engagement, motivation, and conceptual understanding. While challenges exist in terms of technology access and content development, the promising results indicate that VR-based MOOCs could be a valuable tool in improving the accessibility and effectiveness of specialized education in the future

5. Conclusions

The integration of VR with Massive Open Online Courses (MOOCs) offers a scalable and flexible solution that can democratize access to high-quality education in exercise physiology, overcoming geographical and institutional barriers. The positive feedback from both instructors and students indicates that the VR-based MOOC not only supports conceptual learning but also enhances learner engagement through interactive simulations and real-time feedback. Moreover, VR-based assessments provide a more accurate reflection of students' ability to apply theoretical knowledge to practical scenarios, fostering critical thinking and problem-solving skills.

Despite the promising results, challenges related to technology access, content development, and the cost of VR equipment remain significant. However, these obstacles can be mitigated through continued technological innovation and the development of more accessible and affordable VR solutions. Further research is needed to assess the long-term impacts of VR-based learning on knowledge retention and real-world application.

In conclusion, this study highlights VR as a powerful tool for improving the quality and accessibility of education in specialized fields like exercise physiology. As VR technology continues to evolve, it has the potential to revolutionize how complex scientific concepts are taught, making learning more interactive, engaging, and accessible to a global audience.

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