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Exploration on the Reform of Hybrid Experimental Teaching Methods in Biomechanics

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Abstract

Biomechanics, as a crucial foundational course in biomedical engineering, demands an emphasis on cultivating students' practical skills and an explorative mindset. To meet the challenges posed by rapidly evolving technologies and theories, this paper articulates the primary issues confronting traditional biomechanics laboratory teaching. It proposes a reformative approach to blended experimental teaching, integrating online instruction with hands-on practice. The methodology of hybrid experimental teaching in biomechanics unfolds online learning opportunities, encompassing the exposition and application of biomechanical skills. This includes proficiency in image and video analysis, mechanical testing, theory-experimental data comparison, and experimental design. It crafts a well-designed and effective blended teaching program, optimizing corresponding experimental courses, fortifying assessment methods, fostering students' enthusiasm for scientific research, and enhancing their ability to integrate theory with practice. This initiative aims to cultivate innovative and well-rounded talents in the field.

Keywords

Experimental Teaching, Hybrid Teaching, Teaching Exploration

1. Introduction

As a pivotal foundational course in the realm of biomedical engineering, biomechanics is a scientific discipline dedicated to the examination of internal and external motion, structure, and mechanical properties of organisms, encompassing humans and other living entities. Bridging principles from biology, physics, and engineering, biomechanics delves into the exploration of motion, structure, and mechanical attributes inherent in living organisms (Ding et al., 2020).

Within the modern engineering education framework, experimental teaching assumes a crucial role as an indispensable component and an effective tool for fostering students' problem-solving abilities (Wang & Wang, 2015). Biomechanics experimental teaching, being a significant segment of the biomechanics course, aims to deepen students' comprehension of biomechanics principles through hands-on experiences. The objective is to enhance experimental skills, instil scientific methodology, and foster an understanding of patterns of change under diverse experimental conditions. In doing so, it cultivates students' capabilities for scientific research thinking and innovation.

The continual evolution of information technology has spurred a diversified trajectory in teaching methodologies, with online teaching gaining prominence due to its capacity to transcend temporal and spatial limitations (Ma et al., 2022). Traditional teaching approaches, such as classroom instruction and on-site teaching, no longer suffice to meet the evolving demands of biomechanics experimental teaching. In tandem with advancements in virtual simulation and remote network technology, the emerging paradigm of hybrid experimental teaching, coupled with modifications in teaching content, holds promise in augmenting students' practical and scientific research proficiencies (Teng et al., 2019).

2. The Necessity of Constructing a Hybrid Experimental Teaching Framework in Biomechanics

Biomechanics experimental teaching encompasses a diverse range of testing technologies and data analysis, including mechanical experiment design, image and video analysis, and experimental data processing. Historically, laboratory-based experimental class teaching followed a singular instrument operation plan, limiting students' ability to develop personalized practical content aligned with the latest scientific research needs. In the current era of rapid scientific and technological evolution, there is a pressing need to continuously update teaching content to incorporate the latest research results and technological advances. This ensures students are exposed to cutting-edge knowledge, fostering their adaptability to scientific development. Presently, traditional biomechanics experimental teaching encounters four significant challenges:

1) Insufficient attention to experimental preview. Students often overlook the importance of thoroughly understanding and previewing experiments. Merely copying experiment details without grasping the abstract operations can lead to rushed and potentially unsuccessful experimental operations.

2) Need for an enriched experimental teaching model. Traditional classrooms struggle to provide in-depth understanding of experimental principles, especially the specific details of operations. Students tend to mechanically follow experimental handouts, and the time constraints in experimental classes hinder their

ability to think deeply.

3) Improvement in evaluation methods. Current evaluation methods relying on static data records and summary reports may contribute to plagiarism among students. The lack of dynamic recording and playback functions limits the effectiveness and timeliness of evaluations, hindering the cultivation of students' proactive thinking and in-depth exploration.

4) Enhancement of the experimental teaching platform and resources. The global dissemination of educational resources through powerful networks necessitates the continuous evolution of biomechanics theory and practice. Outdated or eliminated experimental projects and methods contribute to a perception among students that the acquired knowledge lacks practical application, diminishing their interest in learning.

Addressing these challenges requires ongoing reform and innovation in teaching content and methods within biomechanics experimental courses. This adaptation is essential to meet the unique demands of such courses and to facilitate the cultivation of students' advanced scientific research and innovation capabilities.

3. Exploring Teaching Methods

Addressing the challenge of cultivating students' abilities to discover, analyse, and solve problems, master scientific experimental methods, and foster innovation in experimental teaching has become imperative (Zhou, 2018). The advent of modern information technology has paved the way for an enhanced pedagogical approach—online and offline hybrid teaching. This approach not only better reflects the interactivity in the experimental teaching process but also aligns with the psychological characteristics of young learners, offering a flexible, convenient, and efficient teaching method (Zhang et al., 2023). The blended teaching model effectively mitigates the shortcomings of traditional approaches by seamlessly integrating online and offline learning methods. This integration provides students with increased learning opportunities and diverse educational methods. Leveraging virtual simulation experiments, recorded teaching videos, and network platforms, among other online resources, in conjunction with offline practical teaching, not only reduces experimental costs but also supports personalized learning for students. Compared to traditional experimental teaching, the hybrid approach organically combines digital resources with hands-on experiments, offering a more comprehensive, interactive, and flexible practical experience (Ochia, 2021). This innovative method aids students in better understanding and mastering biomechanical principles. Moreover, its flexibility in expanding teaching content across time and space helps students broaden their horizons, catering to the diverse learning needs of students at various levels. Experimental teaching, centred on fostering students' hands-on and operational capabilities, fundamentally diverges from theoretical instruction. The teaching methodology employed in the biomechanics experimental course embraces a sophisticated three-in-one hybrid model encompassing "MOOC + virtual simulation experiment + live lectures and interactive Q&A". The development of online courses liberates instructors from the constraints of traditional teaching methods, enabling a departure from mundane teaching processes. This freedom allows educators to focus more on the reconstruction, screening, design, guidance, and innovation of course content, ultimately enhancing the quality of experimental teaching. The hybrid mechanics experimental teaching model, built upon MOOC, is delineated into three distinct stages.

3.1. Preparation Prior to Class

One week before each class, students are required to engage with relevant online teaching videos available on the dedicated online learning platform (Fu & Ding, 2020). This platform boasts several key functions crucial for supporting blended teaching methodologies. These functions include access to experimental videos, self-test questions, discussion forums, and classroom quizzes. In the initial phase, students focus on watching experimental videos to gain foundational knowledge, understanding the use of instruments and equipment, and grasping essential experimental principles. This preparation is essential for their active participation in offline experimental courses. Furthermore, students are tasked with mastering the use of virtual simulation software such as Abaqus, Ansys, and Comsol, enabling them to simulate experimental content by setting the same parameters as the experimental test conditions. This series of online learning tasks empowers students to apply theoretical knowledge in practical scenarios, anticipate the experimental process, and refine their skills in experimental operations and scientific research. To ensure the effectiveness of this innovative approach, experimental teachers actively track students' learning progress through the online teaching platform. They promptly address and respond to students' feedback, creating a dynamic and supportive learning environment. This holistic strategy not only enriches students' understanding and application of biomechanical principles but also fosters a collaborative and engaging educational experience.

3.2. Arrangements during Class

Biomechanics experimental teaching integrates online courses with on-site experimental sessions in a comprehensive approach. The teaching process involves live teaching sessions and interactive Q&A. Teachers utilize platforms like ZOOM to conduct real-time interactions, answering queries and fostering a space for students to discuss relevant knowledge points and seek clarification on experimental procedures. To maintain engagement, teachers pose engineering questions for student responses, encouraging enthusiasm for learning. Additionally, the teaching team collects and researches marginal subject questions and areas of student interest, laying the groundwork for enhancing subsequent experimental courses.

Subsequently, the offline experiment phase ensues, requiring students to actively engage in real-life experimental procedures within the laboratory. The prior learning and practice contribute significantly to a notable reduction in the error rate during students' experimental operations. In response to diverse individual needs, students are afforded the flexibility to choose specific experimental courses, design their projects, or initiate experimental endeavours. Teachers provide on-site guidance and address queries directly within the laboratory setting.

During offline experimental courses, educators immerse students in in-depth discussions on intricate course content and swiftly address any questions students may pose before class. This streamlined approach not only shortens teaching duration but also grants students enhanced opportunities for profound contemplation and practical applications. Throughout the entire experimental course, students assume the primary role in executing mechanical tests and data analysis, with the experimental instructor playing a supportive role. The principal responsibility is to guide students in conducting independent experiments and aiding in troubleshooting and query resolution. In instances of common problems or special cases, the experimental instructor offers concentrated explanations and analyses. This teaching model is strategically designed to augment students' proficiency in independent learning and problem-solving.

3.3. Post-Class Summary

Following the experimental phase, students are encouraged to actively share and exchange their insights and recommendations garnered from the experimental course. Students are required to submit their virtual simulation experiment reports through an online platform, where teachers meticulously review, grade, and provide evaluations. Leveraging big data analysis technology, the online problem discussions, assignments, and other aspects are comprehensively assessed. This approach ensures a thorough and impartial summarization of student learning, facilitating a comprehensive analysis of the learning data. The aim is to offer robust and credible support for refining subsequent iterations of the hybrid teaching model. Students' express satisfaction with this blended experimental teaching approach, highlighting its efficacy in honing their experimental operation skills. Additionally, they derive a sense of fulfilment and joy from the successful design and execution of their own experiments.

Pre-class scores primarily serve to evaluate students' independent learning and problem-solving capabilities, aiming to ignite and encourage their enthusiasm for learning. Classroom scores are predominantly employed to assess students' comprehensive skills in practical operations, teamwork, coordination, and effective problem-solving. Post-class results are geared towards evaluating students' performance in terms of experimental proficiency and overall application abilities. The design of this multi-level assessment and evaluation system contributes to a more comprehensive and objective understanding of students' performance in experimental teaching. Consequently, it fosters their holistic development across knowledge, skills, and overall literacy. Such a system not only facilitates the provision of personalized learning support but also aids students in accumulating the essential abilities and qualities required for their future academic and professional pursuits.

4. Teaching Content Reform

Aligned with contemporary educational principles, we have embarked on a journey of innovation in both the content and methodologies of biomechanics experimental teaching. Our goal is to establish a foundational, comprehensive, and research-oriented experimental teaching system that not only imparts knowledge but also cultivates students' capacity for research-oriented scientific thinking. We aim to equip them with the essential skills of observation, operation, and comprehension of experimental phenomena. In the foundational experimental projects, our primary emphasis is on cultivating students' standardization and proficiency in executing experimental operations (Bai et al., 2022). Special attention is given to ensuring correct usage of commonly employed instruments and equipment in biomechanical experiments. Moving beyond mere theoretical knowledge, we emphasize practical competence to enhance students' hands-on skills. Transitioning to comprehensive experimental projects, we introduce higher-level and challenging experiments. This deliberate choice exposes students to more intricate situations and complex problems, fostering resilience and adaptability in their approach to experimental scenarios.

Building upon the foundational teaching objectives and content, and in close alignment with the characteristics and evolving trends of the discipline, we seek to enhance the existing "force platform and its application" experiment within the biomechanics experimental course. This augmentation encompasses improvements in both experimental content and design. For instance, in biomechanical experiments like gait analysis, we employ recorded teaching videos where instructors demonstrate and discuss normal and pathological gaits. Students engage in virtual simulation software to manipulate walking speed, observe resultant changes in gait parameters, and subsequently conduct statistical analyses using Matlab software. In experiments such as axial load mechanics tests, students are tasked with designing experiments, collecting and organizing data. They then compare their findings with theoretical calculations simulated through finite element software. This approach aims to cultivate students' independent capabilities in experimental design and error correction, fostering a proactive and adept approach to scientific inquiry. To enhance comprehension of the temporal evolution of stress and strain principles, students can benefit from online preview videos. This digital preview not only enhances students' learning efficiency but also equips them with a deeper understanding and practical application of fundamental theories in dynamic mechanics frequently employed in biomechanics experiments during hands-on classes.

The online teaching framework for biomechanics experiments is meticulously organized into five modules to optimize students' preparation and engagement. These modules are strategically designed to seamlessly integrate theoretical knowledge with practical applications, fostering a more immersive and efficient learning experience.

1) Pre-experiment Preparation Module: This initial module provides students with detailed guidance on pre-experiment preparations, emphasizing the correct utilization of mechanical measuring instruments and corresponding software skills. By gaining a comprehensive understanding of experimental content beforehand, students are better equipped for successful offline operations.

2) Image Analysis Module: Tailored for motion analysis experiments, this module offers preview and review materials related to image and data processing. Students learn how to analyse image data generated during experiments, thereby deepening their comprehension of kinematic principles.

3) Tissue Structure Module: Geared towards experiments involving biological tissue mechanics testing, this module furnishes students with preview and review materials on sample structure. Delving into the intricate structure of biological tissues, students establish a foundational understanding crucial for tissue mechanics testing in subsequent experiments.

4) Numerical Simulation Module: Augmented by instructional videos on mechanical measuring instrument usage, this module provides numerical simulations of diverse biomechanical experiments. By engaging in virtual simulations, students familiarize themselves with experimental principles and operating procedures, fostering a more nuanced understanding.

5) Comprehensive Experimental Module: This module integrates various experiments, delivering in-depth preview and expansion materials on background knowledge. Students have the opportunity to apply and refine the knowledge and skills acquired in previous modules through scientific research operations. This approach facilitates the synthesis of theoretical knowledge and practical operations, nurturing students' problem-solving abilities.

The synergistic amalgamation of these five modules enables a structured introduction to the realm of experimental courses in online teaching. Students gain early exposure to various facets of experiments, allowing for targeted and efficient learning in the offline environment. Simultaneously, teachers can flexibly adapt their teaching methods based on students' mastery levels, achieving a more personalized and adaptive teaching approach. Blended experimental courses alleviate the time constraints inherent in traditional formats, allowing students ample time for in-depth contemplation and practical engagement. This approach not only optimizes the utilization of experimental equipment and resources but also enhances overall efficiency. In the upcoming phase, feedback on this hybrid biomechanics experimental teaching method will be collected through hands-on instruction and communication with students. In the realm of biomechanics experimental teaching, blended learning adheres to the pedagogical principle of "prioritizing practicality, supplementing it with tailored needs, and harmonizing the virtual and the real." By adeptly integrating traditional teaching methods and online instructional models, these approaches mutually reinforce each other, resulting in a synergistic enhancement of the overall teaching efficacy. This integration empowers students to comprehensively grasp both the theoretical underpinnings and practical intricacies of biomechanical experiments.

5. Conclusion

The experimental component holds paramount significance in the biomechanics course, serving as a cornerstone for cultivating students' innovative abilities and practical skills. This hybrid experimental teaching approach aims to tailor improvements based on actual conditions, nurture students' practical operational capabilities, and instil a spirit of exploration while steadfastly upholding the integration of theory and practice. The methodology of biomechanics hybrid experimental teaching unfolds online learning opportunities, encompassing the exposition and application of biomechanical skills. This includes proficiency in image and video analysis, mechanical testing, theory-experimental data comparison, and experimental design. Students are guided in operating various instruments through instructional videos and online digital resources meticulously crafted by teachers. The seamless integration of these online elements with offline practical teaching results in a curriculum that is both engaging and informative. Participation in hybrid laboratory courses offers students not only hands-on experience, a realm often challenging to attain in traditional theoretical courses, but also facilitates the development of a spectrum of crucial skills. These skills, cultivated through the hybrid approach, are poised to exert a profound impact on their future endeavours in the realms of biomechanics and bioengineering.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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