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Exploration on the Reform of Teaching Methods of Human Function Replacement Devices under the Background of Educational Informatization

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Abstract

The human function replacement device course is a basic course in the medical device major in biomedical engineering, which is comprehensive, applicable, and practical. As a multidisciplinary cross-disciplinary course, it has many knowledge points, covers a wide range of fields, and develops rapidly, which brings great challenges to teaching. With the rapid development of educational informatization, to improve the teaching effect and quality, it is necessary to integrate the new products, new technologies, new materials, and new processes of modern rapidly developing medical devices into the teaching methods and content. This paper analyses the main challenges faced by the teaching of traditional human function replacement devices, and proposes the integration with modern information technology, and explores the reform of teaching methods, teaching content and practical teaching. It aims to cultivate high-level and high-quality talents adapted to the field of medical devices.

Keywords

Human Function Replacement Device, Teaching Exploration, Educational Informatization

1. Introduction

The course on human function replacement devices is a fundamental component of medical device research within the field of biomedical engineering. This course focuses on medical devices and products, analysing their working principles, mechanical structures, system control, clinical applications, parameter design, and the medical foundations related to lesions.

In recent years, advancements in computing technology have significantly transformed teaching methods. These changes have included a shift from traditional blackboard writing to the use of course slides, from static picture presentations to dynamic audio and video applications, from individual teacher-led explanations to collaborative classroom group discussions, and from straightforward knowledge dissemination to project-oriented teaching (Fu & Ding, 2020). Effectively leveraging various information-based teaching methods is a crucial aspect of current educational reform (Luo, 2024).

With the rapid development of medical device products, it is essential to integrate new technologies, materials, and processes into the curriculum promptly. Traditional classroom teaching methods are increasingly inadequate to meet the evolving requirements of human function replacement device education. In the context of educational informatization, teaching methods must adapt to new challenges and needs.

Educational informatization offers opportunities to optimize teaching content, introduce modern teaching methods, and enrich teaching resources (Liu & Ya, 2013). This approach can enhance students' interest in learning, improve their innovation abilities and practical skills, and ultimately elevate the quality of education. By implementing these reforms, the course on human function replacement devices can better prepare students for the dynamic and rapidly advancing field of medical device research, ensuring they are equipped with the knowledge and skills necessary for their future careers.

2. Necessity of Informatization Construction of Teaching of Human Function Replacement Devices

The course on human function replacement devices encompasses a variety of medical devices, including artificial kidneys, artificial hearts and lungs, and ventilators. Each module provides a comprehensive explanation of the diseases targeted by these devices, their working principles, main structures, and clinical applications. This course emphasizes the integration of medicine and engineering, balancing theoretical knowledge with practical application. Students are required to have a solid foundation in theoretical knowledge and extensive practical experience in instrument analysis.

This course involves multidisciplinary knowledge, including chemistry, physics, mathematics, and computer science, each with its own distinct principles. The diverse structures of medical devices, being multidisciplinary and high-tech intensive, add to the complexity of learning (Xie, 2018).

Given the rapid advancements in the medical device industry, products are evolving towards diversification, intelligence, and systematization. Consequently, teaching content must be continuously updated to incorporate the latest scientific research and technological advancements. Strengthening integration with modern information technology ensures that students are exposed to cutting-edge knowledge and develop the ability to adapt to scientific progress.

Currently, the primary challenges in traditional teaching methods for human function replacement devices include:

1) Theoretical instruction in the human function replacement devices course tends to be abstract, with teaching methods remaining relatively simplistic. Current textbooks allocate excessive space to the theoretical aspects of various medical device analysis methods, while practical application examples relevant to production and everyday life are rarely included. This disproportionate emphasis on theory over practical examples results in a lack of connection to real-world analysis practice, making it challenging to engage students and stimulate their interest. Traditionally, instructors start with explaining the fundamental principles and concepts of human function replacement devices, followed by introducing medical device structures and concluding with an overview of analysis method applications. This sequential teaching method often leads to an abstract and monotonous learning experience, hindering students' active participation and engagement. Additionally, the course fails to adequately highlight the professional characteristics of the field, lacking effective integration with subsequent professional courses, which impedes students' development of professional competencies and readiness for real-world work environments.

2) The current curriculum suffers from outdated content and insufficient coverage of cutting-edge knowledge. The course predominantly focuses on classic medical device analysis methods, some of which are obsolete, with minimal inclusion of contemporary technologies in analysis and testing. This lack of timely updates contrasts sharply with the rapid advancements in human function replacement devices. Consequently, outdated content consumes valuable classroom time and undermines effective teaching of core concepts. The absence of cutting-edge technical knowledge impedes students' comprehensive understanding of evolving trends and advancements, dampening their curiosity and enthusiasm for exploration. This deficiency not only hinders students' grasp of modern technology but also stifles the development of their innovative thinking.

3) The experimental teaching model for human function replacement devices is currently inadequate and lacks a structured approach. Given its practical nature, this course demands that students grasp fundamental principles and develop familiarity with basic device structures and operations through hands-on tasks. Practical experience enhances their proficiency in applying theoretical knowledge. Presently, the traditional approach involves instructors explaining basic principles, structures, and safety precautions. Students then follow guided steps to conduct experiments and subsequently complete experimental reports. However, this method results in extended teaching durations, insufficient time for meaningful student engagement, and suboptimal practical training outcomes. Furthermore, the experimental teaching framework lacks a hierarchical structure, failing to establish a systematic progression from basic to comprehensive and design-oriented experiments. This absence complicates the effective cultivation of students' comprehensive application and innovation abilities.

4) Course assessment primarily emphasizes knowledge acquisition over skill development. Due to constraints like chapter divisions and question formats, theoretical examinations heavily feature objective questions, with limited opportunities for application questions that foster analytical and problem-solving abilities. This assessment approach overlooks the crucial role of cultivating practical application and innovative capabilities, thereby narrowing students' focus to theoretical knowledge and medical device structures. Similarly, experimental assessments overly emphasize outcomes without adequately evaluating students' operational skills and application capabilities. This deficiency hinders experimental course assessments from accurately and comprehensively measuring students' progress in practical training and enhancement of application abilities. Therefore, there is an urgent need to reform course assessment methods to better align with the goals of skill development and comprehensive learning outcomes.

3. Exploring Teaching Methods

The essence of reform in teaching human function replacement device courses lies in establishing a robust connection between abstract theoretical instruction and specific analysis and testing practices, aimed at nurturing application-oriented and innovative talents. In the era of modern information technology, digital teaching plays a pivotal role in optimizing course content, developing comprehensive digital teaching resources, and innovating teaching methodologies (Li et al., 2024). Alongside delivering educational content through digital platforms, educators should integrate the latest advancements in medical devices, including developments in new components, materials, and manufacturing processes. They should also address technical challenges and practical issues encountered in the application of medical device products, particularly focusing on the R&D complexities faced by relevant companies.

As computer technology becomes more pervasive and educational informatization advances, digital tools have become integral to normalized teaching practices due to their inherent advantages such as intuitiveness, dynamism, interactivity, repeatability, information concretization, and expansive data capacity (Liang et al., 2021). Educators predominantly utilize pre-prepared multimedia courseware to present and elucidate knowledge. By incorporating virtual simulation experiment platforms, online resource repositories, and multimedia teaching aids, instructors can vividly and intuitively demonstrate intricate theories and operational procedures related to cutting-edge medical devices. The synergistic integration of digital resources with traditional classroom teaching fosters a more comprehensive, interactive, and adaptable learning environment, enabling students to grasp the principles of medical devices more effectively.

Moreover, this approach transcends temporal and spatial limitations, enriches the scope of teaching materials, broadens students' perspectives, and caters to diverse learning requirements across different proficiency levels. Information-based teaching methods, pivotal in the educational informatization era, emphasize interactive, personalized, and flexible learning experiences. These methods leverage digital tools to foster engagement through interactive content and immediate feedback, while adaptive learning technologies tailor educational resources to individual needs. They enhance accessibility, allowing students to learn anytime and anywhere, and promote inclusivity through diverse learning formats.

Additionally, group discussions and case analysis methods can be implemented to foster student initiative and facilitate project-oriented learning on specific research topics, integrating PBL (Problem Based Learning) methodologies into both classroom and extracurricular teaching. These approaches build upon theoretical instruction by incorporating practical teaching components that allow students to engage directly with the research methods pertinent to human function replacement devices, enhancing their comprehension and retention. PBL, a student-centred and problem-oriented approach, empowers students to independently gather information, identify issues, and develop solutions through guided teacher facilitation during group discussions. This process cultivates students' ability for self-directed learning and innovation (Lan & Wang, 2013).

To effectively cultivate application-oriented competencies, teaching in human function replacement devices should prioritize real-world application problems that not only stimulate student interest but also align closely with educational objectives. During the exploration of teaching reforms, educators should design specific case studies drawn from clinical, research and development, and everyday contexts to address targeted application problems related to theoretical concepts and analytical challenges. Employing multimedia digital tools as the primary medium, supplemented by traditional blackboard instruction and practical demonstrations, ensures a comprehensive undergraduate education in human function replacement devices for students pursuing biomedical engineering.

Enhance the alignment of teaching content with product development and scientific research projects, employing case analysis and discussions to engage students in solving practical research challenges. By integrating modern information technology with traditional teaching approaches, develop a human function replacement device curriculum characterized by expansive perspectives, innovative content, and a coherent structure. This approach aims to foster students' innovation capabilities and overall competence, addressing societal needs for skilled innovators.

Regarding teaching evaluation, a comprehensive approach can be adopted, integrating exercises, post-class open-ended questions, experiments, and written tests. Online digital platforms facilitate tracking students' learning progress, allowing timely collection and response to student queries. Detailed records on students' activities such as video viewing and exercise submissions on the online platform enable teachers to accurately assess students' learning processes and provide a robust basis for ongoing evaluation. This multifaceted evaluation strategy ensures a thorough examination of students' proficiency in the human function replacement device course, effectively reflecting the overall teaching outcomes.

4. Teaching Content Reform

As a foundational course for students in biomedical engineering and related disciplines, the evolution of human function replacement devices exemplifies how scientific thought and innovative awareness lead to the creation of novel tools and methods for practical challenges. Consequently, in the pedagogical approach to human function replacement devices, educators should consistently emphasize the cultivation of students' innovative thinking. To foster engagement, instructional materials such as relevant images, animations, and videos should be integrated extensively throughout the curriculum (Wang et al., 2019). By posing questions such as "What constitutes a human function replacement device?", "What aspects of medical devices are studied?", and "How have artificial kidneys, artificial heart-lung machines, and ventilators evolved?", instructors can guide students toward an intuitive grasp of human function replacement devices and their technological advancements.

With the advancement of information technology and the internet, information-based education has become increasingly prevalent. Online courses, as a primary form of such education, have garnered significant attention in higher education. Developing online courses for human function replacement devices can effectively leverage existing online educational resources and integrate cutting-edge advancements in new products, technologies, materials, and processes of medical devices into the curriculum (Huang, 2019). This involves strategically organizing and aligning the core knowledge points related to medical devices, planning course progression, facilitating teacher-student interactions, employing diverse learning and assessment methods, enhancing online learning monitoring techniques, implementing various assessment strategies, and offering post-class tutoring and communication. These efforts aim to enhance student engagement in online learning and elevate the overall teaching quality of these courses.

To address the issue of outdated teaching content in human function replacement device courses, a strategic approach can be implemented to minimize outdated technologies and older instruments. While some medical device technologies may be dated, they remain essential for students to comprehend foundational analytical principles. Therefore, these topics should be delivered in a self-directed learning format for students, supplemented by teacher-led instruction. For instance, in teaching about oxygenators for artificial heart-lung machines, although bubbler oxygenators are outdated, they provide insight into gas diffusion and the blood-gas interface. Students can independently study this content outside of class, while teachers focus on contemporary topics such as the structure and operational principles of membrane oxygenators that better align with human physiological conditions. Visual aids such as flowcharts, relationship diagrams, and itemized lists can be employed by teachers to emphasize key concepts and enhance clarity (Shen, 2018). Particularly when explaining the arrangement and structural design of membranes in hollow fibre membrane oxygenators, integrating digital information can improve visual comprehension and facilitate student understanding. By optimizing teaching content in this manner, students can efficiently grasp the historical development of medical devices while mastering the principles and structure of modern human function replacement devices, thereby fostering their innovative thinking abilities.

In the context of educational informatization, PBL methods can effectively illustrate examples of technology and method innovation in human function replacement devices. Teachers can frame technological or methodological innovations as specific challenges, guiding students to analyze and discuss the innovative aspects of medical devices. This approach allows students to engage directly with the pioneering thought processes involved. By showcasing the functionalities and innovative features of state-of-the-art medical devices through videos, students can grasp that advanced technology often represents enhancements to existing equipment, thereby enhancing their comprehension of technological innovation.

The course on human function replacement devices emphasizes both theoretical knowledge and practical application, with a significant emphasis on hands-on teaching methods. Integration of digital tools enhances learning experiences through virtual simulation experiments, recorded videos of experiments, and online platforms. These information-based resources allow students to simulate, preview, and review experiments in virtual environments, facilitating better understanding of experimental principles and procedures. For instance, using finite element simulation to analyse flow field distribution, pressure variations, and velocity gradients in centrifugal pump impellers enables optimization of impeller geometry to enhance pump efficiency. Hands-on practice with simulation software equips students with design knowledge and fosters computer simulation skills, crucial for future engineering endeavours.

Shifting theoretical instruction, medical device structure introduction, and operational guidelines in human function replacement device experimental classes from in-person teaching to online formats or video-based learning addresses the challenge of limited experimental teaching time effectively. This approach frees up more time for students to engage in actual hands-on experimental training, thereby enhancing their practical competencies.

5. Conclusion

The advancement of networked information education has spurred innovation in teaching methodologies for courses on human function replacement devices. Integrated with the PBL approach, these methods are guided by practical application challenges and examples of innovative development, placing students at the centre to foster application-oriented skills and drive teaching reforms. Optimization of teaching content involves integrating innovative examples and advancements in instrument analysis technologies, enhancing students' capacity for innovative thinking. Diverse evaluation methods enable students to assess their strengths and weaknesses comprehensively in both theoretical understanding and practical application, preparing them for dynamic professional environments. The reconstruction of the teaching process through information technology, particularly with the hybrid teaching model, surpasses traditional methods by better engaging students' initiative and enthusiasm. This approach supports the holistic development of students across knowledge acquisition, skill development, and personal qualities. Digital tools are leveraged to impart foundational principles and knowledge of medical device products, continuously updating content with new products, concepts, materials, and processes. By eliminating constraints of time, location, and physical resources, this approach fosters students' innovative spirit, initiative, and enthusiasm. It equips them to stay abreast of the rapid advancements in the medical device industry and cultivate high-calibre talents demanded by the field.

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Conflicts of Interest

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

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