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ARTICLE

Toward a Curricular Reform: Reimagining the Mechanical Design Foundation for Biomedical Engineering Education

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Abstract

This paper systematically explores directions for curriculum reform. It addresses two core issues: the disconnect between the "Fundamentals of Mechanical Design" course and BME students' professional needs, and the curriculum's tendency to be broad but shallow. First, it analyzes the conflict between the highly interdisciplinary nature of the discipline and limited instructional hours, revealing the current status characterized by content oversimplification, a disconnect between learning and application, and insufficient student motivation. Accordingly, a specific scheme for reconstructing the curriculum based on a "problem-oriented" approach is proposed. By integrating four interdisciplinary modules—Rehabilitation Engineering, Biomechanics, Sports Biomechanics, and Human Factors Engineering—the scheme deeply combines traditional mechanical principles with the practice of medical device design. The paper further discusses the pedagogical paradigm shift from "tool-oriented" to "problem-oriented" represented by this reform, and objectively analyzes the practical challenges regarding faculty, resources, and evaluation systems, as well as the potential impact on the disciplinary ecosystem. In conclusion, it is noted that this reform constitutes a systemic reconstruction of the curriculum system. It aims to cultivate interdisciplinary engineering talents capable of solving complex clinical problems, holding significant value for aligning with national strategic demands and promoting the specialized development of the major.

Keywords: Biomedical Engineering; Mechanical Design Course; Curriculum reform; Problem-based teaching

1. Current Status of the Discipline and Curriculum

The core objective of traditional engineering (such as mechanical, electronic, and chemical engineering) is to address problems in the fields of industry, energy, and information, with its logical starting point rooted in the physical world and engineering demands[1].In contrast, the logical starting point of Biomedical Engineering (BME) lies in living systems and clinical medical needs. Its interdisciplinary nature of medicine and engineering is manifested in the fact that engineers must first understand, translate, and define biomedical problems, and subsequently convert them into technical problems that can be modeled, analyzed, designed, and verified using engineering language. In this process, engineering innovation serves medical comprehension, which in turn drives further engineering innovation[2]. Therefore, this discipline involves not only corresponding engineering knowledge across multiple directions (such as mechanical design, biomechanics, control theory, materials science, and electrochemistry) but also medical knowledge ranging from molecules and cells to tissues, organs, and the entire human body, encompassing disease diagnosis, treatment, rehabilitation, and prevention[3] . Evidently, BME is significantly distinct from traditional engineering, and the engineering knowledge it entails also differs substantially. This paper will focus on the field of mechanical design involved in the BME major. From the perspective of educators and combined with the experiences of students in this

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major, it explores the future pedagogical reform directions for relevant courses and knowledge in Chinese universities.

The BME major is characterized by a high degree of interdisciplinary integration, resulting in a broad scope of curriculum design. Undergraduate students in this major are required to simultaneously study core knowledge from three major domains: engineering, medicine, and science. First, students are expected to master a profound mathematical and scientific foundation as well as engineering skills, such as advanced mathematics, circuit analysis, signal processing, programming, and college chemistry, which serve as tools for solving engineering problems [4] . Second, students must understand the human body and diseases, necessitating the study of medical courses like anatomy, physiology, and cell biology. Furthermore, students are exposed to highly specialized core courses including biomechanics, biomaterials, medical imaging, and artificial intelligence [5].

1.1. Overview of the BME Curriculum

Within the limited timeframe of undergraduate studies, such a broad curriculum can pose practical challenges for students. Simultaneously studying multiple engineering branches and medical knowledge easily leads to a situation of "learning broadly but lacking in depth," making it difficult to form core competitiveness in a specific field. Effectively integrating fragmented engineering and medical knowledge to solve real clinical problems is a high-level challenge. Experts have pointed out that the current disciplinary system is "relatively fragmented with poor system integration" [5]. Moreover, faced with numerous frontier directions (e.g., AI medical imaging, wearable devices, biomaterials), students often feel disoriented and need time to identify their personal academic interests. This "broad but shallow" experience, along with subsequent career prospects, is also closely related to the institutional background. Universities with strong engineering backgrounds emphasize engineering principles such as electronics, information, and instrumentation, giving their graduates an advantage in further studies or employment in electronic information and computer fields [6-7]. Medical universities are more aligned with clinical needs and may incorporate clinical internships to cultivate applied talents [8-9].

From a personal perspective, the breadth at the undergraduate level serves to construct an interdisciplinary knowledge system, providing a wider range of choices for future advanced studies. What is crucial is to identify and delve into a specific direction as early as possible in the senior years. By engaging in the "undergraduate tutorial system," scientific research projects, competitions, or internships, students can apply theoretical knowledge to specific problems, thereby enhancing their depth of understanding. Due to the high research and development threshold of the industry, a high proportion of students in this major pursue further studies. The postgraduate stage is critical for completing the transition from "broad" to "deep." The "broad but shallow" nature of the BME major is an inherent characteristic of the discipline; it presents a challenge but also offers students vast possibilities. The key to success lies in actively transforming this "breadth" into unique, multifaceted personal competitiveness through early exploration, active practice, and clear planning.

1.2. Current Status of Mechanical Courses in the BME Major

Universities offering undergraduate BME programs generally include courses such as "Mechanical Design." However, the lack of depth in these courses is a typical manifestation of the "broad but not refined" status quo of the major. This "simplified" engineering curriculum stems from the practical dilemma of balancing the "medicine-engineering interdisciplinary" knowledge system within limited credit hours.

The knowledge system of this major possesses inherent contradictions. BME needs to integrate multiple fields including electronics, computer science, medicine, biology, and mechanics. Under the constraint of total credits, the instructional hours allocated to a single engineering direction (including mechanics) are inevitably limited. Studies have explicitly pointed out that in some medical universities, fundamental engineering courses like mechanical design are often treated as "non-examination assessment courses," and in some cases, they are not offered at all or lack continuity with subsequent courses.

Due to the different emphases in the training objectives of the major, the learning foundation and atmosphere vary. The core objective of BME is to cultivate engineers capable of solving medical problems, where application outweighs deep theoretical exploration. The courses focus more on enabling

students to understand the mechanical principles involved in medical devices (e.g., prosthetics, artificial joints) rather than training them to become mechanical design experts. In BME programs at medical or comprehensive universities, the engineering atmosphere is relatively weak. Students generally lack interest in engineering and prerequisite knowledge, necessitating a lower threshold for teaching. Teaching practices have revealed that BME students generally perceive mechanical courses as less essential than medical courses[10], leading to poor learning initiative, which in turn restricts the room for increasing course difficulty. In contrast, foreign universities (e.g., Queensland University of Technology) offer specialized courses like "Modeling and Simulation in Biomedical Engineering Design" at the advanced stage of BME. This course requires students to master in-depth content such as nonlinear finite element analysis and hyperelastic simulation of biomaterials[11], which are precisely what the "Fundamentals of Mechanical Design" courses in many domestic undergraduate BME programs fail to cover.

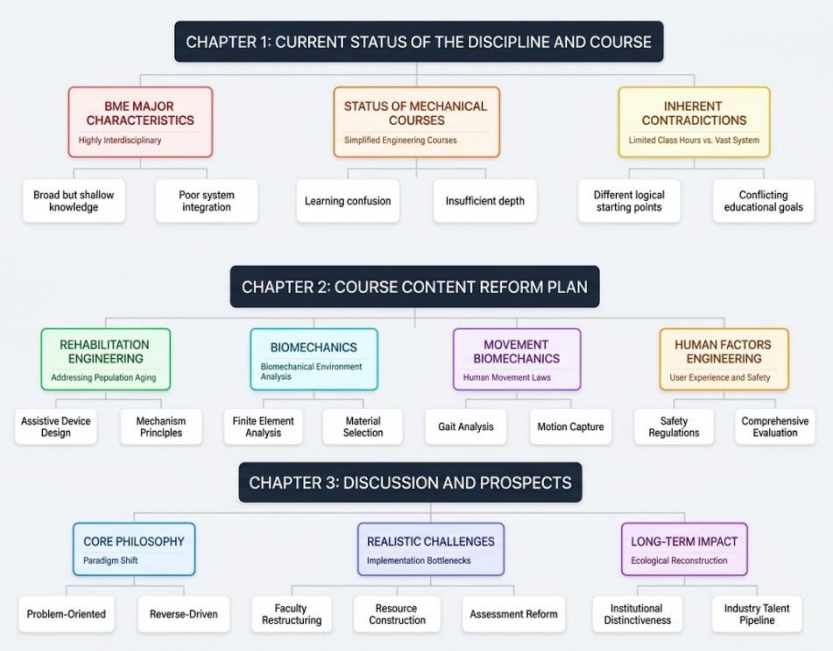

Figure 1. The logical flow of this paper

Chapter 1 of this paper points out that the logical starting point of Biomedical Engineering is living systems and clinical needs, which is completely different from traditional engineering. It concretizes and phenomenologizes this contradiction, highlighting that current mechanical design courses are simplified compared to other disciplines, suffering from a disconnect between theory and application as well as a lack of depth. Based on this concept, Chapter 2 introduces the reform plan, which mainly includes four representative modules suitable for integration with the mechanical design course: Rehabilitation Engineering, Biomechanics, Sports Biomechanics, and Human Factors Engineering. For each module, the medical value of the field is first elucidated, followed by a precise positioning of the traditional mechanical knowledge points it can be embedded into, and finally, specific teaching cases and practical methods are provided. After proposing the specific plans, the discussion elevates the perspective to examine the profound significance, practical challenges, and long-term impacts of this plan. The underlying logic is: what we are doing is not merely modifying a few courses, but driving a pedagogical paradigm shift from tool-oriented to problem-oriented learning. This reform will face challenges in terms of faculty and resources, but will ultimately transform students' competency structures and the academic ecosystem.

2. Curriculum Content Reform Plan

In view of the current status of the Biomedical Engineering (BME) major and its mechanical design courses, it is necessary to reform the content of the mechanical design curriculum within this major.

Integrating medical-engineering content into BME mechanical design courses is no longer merely an exploration. It is a necessary reform to achieve core educational objectives, meet national societal needs, and enhance students' employment competitiveness. The core value of this reform lies in its ability to transform the knowledge anxiety of "learning broadly but lacking in depth" into a clear goal of "applying what is learned," fundamentally solving the problem of disconnection between curriculum and practice.

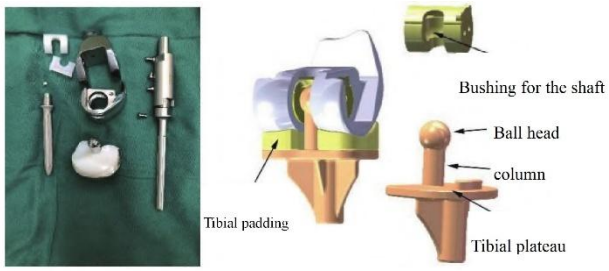

Figure 2. Parts and structure of a knee orthosis[12]

There is a sense of fragmentation between traditional mechanical design courses and practical applications. When teaching the general design of gears, bearings, and shafts, BME students often feel confused, unable to understand the connection between these mechanical structures or principles and their major. This disconnect leads to insufficient learning motivation and low knowledge retention rates. The course format should be adapted as follows: using "the hinge design of a knee orthosis" to explain kinematic pairs and degrees of freedom[12], and using "the force distribution in a prosthetic socket" to explain stress concentration and material selection[13], thereby binding abstract engineering principles with medical objectives such as the human body, diseases, and functional compensation. This achieves a cognitive leap from designing machines to designing for humans. The subsequent sections will detail the reform of the mechanical design curriculum, combining specific contents from different research directions within BME.

2.1. Rehabilitation Engineering

China has entered a deeply aging society, leading to an explosive growth in the demand for rehabilitation assistive devices (prosthetics, orthotics, walkers, smart wheelchairs, etc.)[14]. However, there is an extreme shortage of high-end talents in this field who understand both clinical rehabilitation needs and engineering implementation. Curriculum reform can directly anchor talent cultivation to this national strategy and industrial blue ocean. What students master are not only general skills but also specific abilities to address the "challenges of an aging society," greatly enhancing their social value and employment competitiveness.

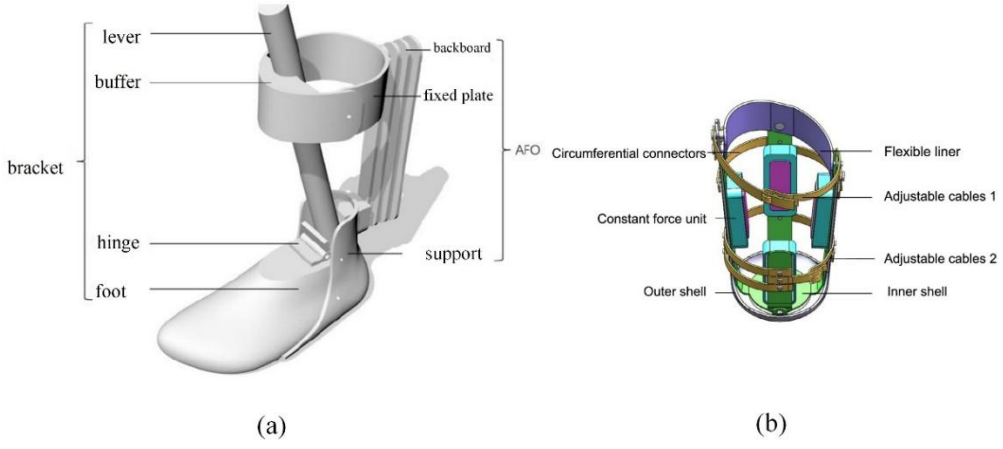

Figure 3. Mechanical structures of two rehabilitation devices: (a) Ankle-foot orthosis[15], (b) Semi-open constant-force prosthetic socket[16]

The design of rehabilitation assistive devices is a typical "optimization problem under complex constraints," involving biomechanics, mechanics, materials science, human factors engineering, and even psychology simultaneously. The reform is not a simple addition of content, but requires a systematic curriculum reconstruction. First, 2-3 "Rehabilitation Assistive Devices Special Topics" chapters should be added to the existing "Fundamentals of Mechanical Design." For these devices, the instruction must be detailed enough to fully display their mechanical structures, mechanism designs, and individual components, thoroughly explaining the coordination methods and kinematic chain principles of each mechanism and component. Using the Knee-Ankle-Foot Orthosis (KAFO) as an example, linkage mechanisms, locking structures, and lightweight design can be explained[15]; using the prosthetic socket as an example, composite materials, interface soft linings, and biocompatibility can be discussed[16]. The final assessment could include a major assignment: designing a simple assistive device for a specific functional impairment (e.g., wrist drop after stroke). By adopting this teaching approach, traditional mechanical principles such as gear meshing and linkage structures are embedded within actual devices. Students' learning will have a clear sense of meaning and purpose, fully cultivating their creativity and applying fragmented knowledge to solve health problems. This helps them break away from the awkward positioning of a "simplified mechanical version" and shape an irreplaceable, distinctive core competitiveness.

2.2. Biomechanics

The study of biomechanics mainly stems from the profound combination of human exploration into the essence of life movement and the demand for practical applications. It is not only an important extension of basic scientific exploration but also a key bridge for solving practical problems in engineering, medicine, and health fields. Many diseases are closely related to the mechanical environment, such as in orthopedics, cardiovascular systems, rehabilitation engineering, and injury prevention[17]. The interdisciplinary value of biomechanics and mechanical design lies in applying the mechanical properties from mechanical design to the complex mechanical environment of biological organisms. Once students master the relevant knowledge, they can gain a deeper understanding of the essence and theory of human-machine interaction interfaces, facilitating further scientific research and the improvement of various devices.

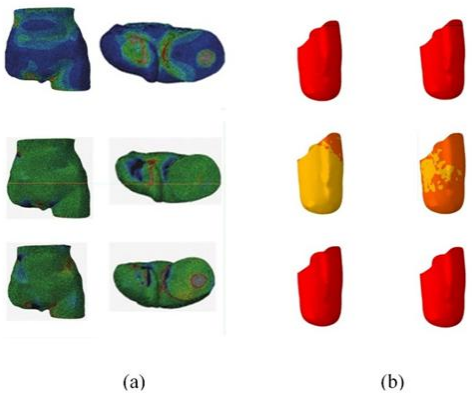

Figure 4. Force distribution of amputees wearing prostheses at different sites: (a) Hip disarticulation amputee[13], (b) Knee amputee[18]

In biomedical engineering, due to the existence of complex material tissues like human body tissues, contents such as finite element analysis (FEA), strength theory, and fatigue analysis should be introduced into mechanical design. These should be deeply integrated with sections like "strength and stiffness calculation of parts," "introduction to finite element analysis," and "fatigue life prediction." When explaining the mechanical properties of materials, the differences in constitutive models between bones (anisotropic), cartilage (hyperelastic), ligaments (viscoelastic), and metallic materials should be compared, introducing the concept of nonlinear analysis. For example, by teaching students to use simulation software (such as Ansys Workbench, Fluent, Abaqus, SolidWorks, etc.)[13,18], an assignment in the "strength verification" chapter could involve designing a knee joint implant, requiring

students to use the software to analyze the stress distribution of the tibial tray under different loads and optimize its shape to avoid bone resorption caused by stress shielding[19]. In the "fatigue analysis" chapter, using an artificial heart valve leaflet as an example, students can simulate its periodic stress under 60-100 pulsations per minute, calculate its fatigue life, and learn about the high-cycle fatigue characteristics of biomaterials[20]. A major assignment could be set requiring students to build a simplified model for a simple bone plate or interbody fusion cage, complete stress simulation under static loads, and write a report analyzing the rationality of its design[21].

Mechanical materials directly determine the safety, efficacy, and biocompatibility of medical devices. Sections on "basis for material selection" and "part failure analysis" should be systematically embedded. Material selection charts should be transformed from general metal fatigue diagrams, stress-strain diagrams, and material mechanical property charts into specific modules for material selection criteria and part failure analysis conditions. The material spectrum should be reconstructed, expanding from traditional metals (steel, aluminum) to medical metals (titanium alloys, cobalt-chromium alloys, shape-memory Nitinol), polymer materials (ultra-high molecular weight polyethylene, silicone, biodegradable polylactic acid), and bioceramics (alumina, hydroxyapatite). For instance, orthopedic implants can be introduced. When explaining the femoral stem of a hip joint, the focus should be on analyzing the matching of the elastic modulus between the titanium alloy and the bone, elucidating how to reduce the elastic modulus difference through porous structure design to promote osseointegration. In the "part failure" section, cardiovascular stents can be introduced. Using vascular stents as an example, the design trade-offs between the radial support force and compliance of metal stents versus the degradation rate and mechanical strength attenuation curves of biodegradable polymer stents can be explained. In the practical session, a clinical scenario (e.g., cranial defect repair) can be given, providing performance data sheets for several candidate materials (titanium mesh, PEEK, autologous bone), allowing students to conduct comparative analysis and complete a material selection justification report[22].

2.3. Sports Biomechanics and Human Kinematics Analysis

This section aims to reconstruct the principles of mechanism kinematics and dynamics from classical mechanical design within the real context of human movement, striving to build a complete methodology from biological movement principles to engineering mechanism design. The core of the reform is to treat the human body as a special and complex mechanical system. By learning how to quantitatively describe and analyze its movement, this knowledge can reversely drive the engineering design of medical devices.

In traditional mechanical design, the objects of kinematic analysis are abstract rigid bodies such as gears and linkages. For BME, the ultimate service object is the "human." Therefore, the curriculum must add a prerequisite and core component: understanding the laws of human movement itself. The contents of this chapter should be systematically embedded into sections like "mechanism kinematic analysis," "linkage mechanism design," and "system dynamics." Students need to be familiar with human gait, where all kinematic parameters of the gait cycle (displacement, velocity, acceleration, joint torque) are directly correlated with specific clinical functions (walking, grasping, standing up) and pathological states (hemiplegic gait, joint contracture). The design objective is concretized from realizing a generic "motion function" to reproducing or assisting a "human motion pattern that conforms to biomechanical optimality." The concept of "human-machine interaction" is introduced, ensuring that mechanism design must consider the real-time feedback and adaptability of human movement, which also lays the foundation for control courses.

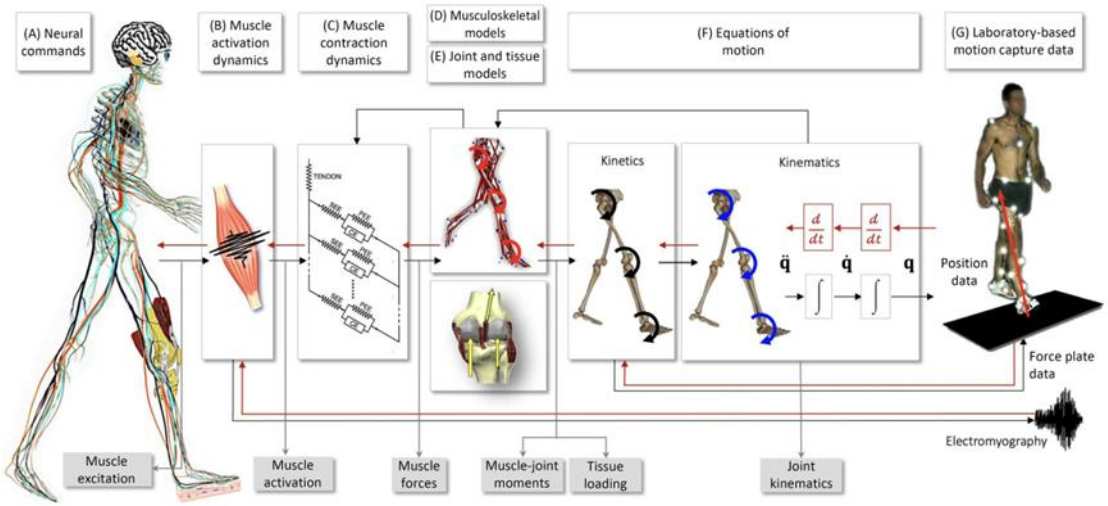

Figure 5. Kinematic angle analysis of hip, knee, and ankle joints during dynamic human walking [23]

The fundamental principles of this section are human kinematics terminology and basic models. First, a descriptive system for human movement is established. Anatomical planes (sagittal, coronal, transverse) and basic motion terms (flexion/extension, abduction/adduction, rotation) are explained. The link-hinge model is introduced, simplifying the human body into a multi-body dynamic system composed of rigid segments (e.g., thigh, shank, foot) connected by rotational hinges (joints). Second, the concept of "degrees of freedom of mechanisms" is correlated and deepened. By analyzing the degree of freedom configuration of the human lower limbs (hip, knee, ankle) during walking in the sagittal plane, students are helped to understand how complex biological systems can be transformed into analyzable mechanical systems through simplified models. A case study involves comparatively analyzing the kinematic differences in the sagittal plane between normal gait and the pathological gait of a stiff knee, guiding students to think about how to compensate for motion loss using a single-degree-of-freedom knee hinge mechanism[23].

To obtain the core parameters of human movement, it is necessary to adopt quantitative and measurement methods of kinematics, systematically explaining the acquisition and calculation methods of kinematic parameters. The phases of the gait cycle (stance phase, swing phase) are detailed, along with the characteristic kinematic and kinetic curves of the hip, knee, and ankle joints in each phase (e.g., the slight flexion buffering of the knee at initial contact, the rapid plantarflexion of the ankle during push-off). Video-based 2D motion analysis (e.g., using open-source software like Tracker, OpenSim, etc.) is introduced, explaining the calibration, data acquisition, and processing workflows. The principles of optical motion capture technology are explained in depth. The focus is on the anatomical basis of marker placement, the establishment and transformation of different coordinate systems (laboratory coordinate system, segment coordinate system), and the mathematical processes for calculating joint angles, angular velocities, and angular accelerations from raw marker coordinates (e.g., based on Cardan or Euler angles). Finally, "motion analysis" is transitioned from theory to practice. The acquired data serve as the input and validation criteria for subsequent mechanism design. For example, by providing a set of marker coordinate data from a public gait database, students are required to write a simple program (or use Excel/MATLAB) to calculate the flexion-extension angle curves of the hip and knee joints during one gait cycle. The angular displacement-time curves of the hip and knee joints directly determine the required range of motion for an exoskeleton or prosthetic knee. Based on the joint range of motion data, the required workspace for the exoskeleton or robotic end-effector is determined. Discussions will cover how to use linkage mechanisms (such as four-bar linkages, serial linkages) or compliant mechanisms to approximately fit the measured physiological motion trajectories.

2.4. Human Factors Engineering

Human factors engineering (HFE) represents the elevation of mechanical design from mere functional realization to the optimization of user experience and safety; it serves as the ultimate evaluation standard for processes such as structural design, dimension determination, and surface

treatment. It should be consistently integrated throughout structural design, tolerance and fit, and comprehensive course design projects. For the human factors engineering of medical devices, it is necessary to integrate multifaceted theories and practical application outcomes. It is an integrative and verifiable systematic discipline that encompasses physical dimensions (biomechanical matching, material biocompatibility, morphology and adaptation, etc.), cognitive dimensions (information design, decision support, etc.), and organizational and environmental dimensions (workflow integration, environmental constraints, culture and ethics, etc.).

Figure 6. Human factors engineering design in medical/rehabilitation device: Wheelchair parameter adaptation [24]

When teaching part structures, specific regulatory guidelines for medical devices should be added. For example, for specific medical devices, there are guidelines such as: syringe connectors must have a unique design to prevent misconnection; the grip force and texture of surgical instruments must match hand anatomy; the inclination angle of wheelchair push handles must ensure wrist comfort[24]; and the symbols and color coding on device control interfaces must align with clinical intuition and allow for rapid identification in emergencies. When conducting design case studies, a user-centered approach should be adopted. For instance, in the "dimensions and tolerances" section, an insulin injection pen can be introduced to analyze how the torque magnitude of its dose adjustment knob, the clarity of its scale, and the design of its "click" feedback sound meet the needs of diabetic patients with poor vision or weak hand strength. In the "structural design" section, a hospital bed can be introduced to analyze how the mechanical principles of its lifting, back-raising, and turning functions achieve a balance between labor-saving single-nurse operation and patient comfort and safety[25]. Regarding the practical component, a "human factors engineering evaluation" module should be mandatorily included in the final comprehensive design project of the course. Students should be required to create user personas for their design proposals (e.g., a home rehabilitation device), conduct task analyses, and propose at least three detailed design improvements based on human factors engineering.

3. Discussion and Perspectives

The curriculum reform plan proposed in this paper possesses both core values and inherent controversies, warranting a multidimensional examination. The concept of "reconstructing engineering knowledge through medical problems" advocated by this plan is not intended to negate or simplify the traditional mechanical design system; essentially, it is a goal-driven paradigm shift. This transformation directly addresses the long-standing dilemma in undergraduate Biomedical Engineering (BME) education: how to enable students to consolidate their engineering foundation while acquiring the ability to solve real medical problems within limited instructional hours.

However, the current approach of superimposing multidisciplinary knowledge within limited courses may exacerbate the contradiction between teaching load and broad learning. In contrast, a more thorough pedagogical reconstruction might be to promote BME students to stream into specific fields—such as rehabilitation engineering, biomechanics, human kinematics, or human factors engineering—earlier and more deeply. We emphasize that there must be a more precise streaming within the broad discipline of Biomedical Engineering. For instance, in the mechanical learning modules, some students may focus exclusively on the content related to wheelchairs, while others concentrate solely on prosthetics, rather than having all students cover every topic and end up with only a superficial

understanding of multiple application areas. We believe that early and thorough streaming is necessary. On this basis, mechanical design textbooks for various directions should deeply integrate the professional content of their corresponding fields, rather than attempting to amalgamate all knowledge within a thin teaching framework. Research indicates that this focused training pathway is more conducive to helping students build a solid and specialized knowledge and competency system.

3.1. Core Concept of the Reform: From "Tool-Oriented" to "Problem-Oriented"

Traditional mechanical design courses follow a tool-oriented logic, where the pathway begins with learning general principles, proceeds through mastering design tools, and ultimately points to solving hypothetical industrial problems. However, for the BME major, this chain is often broken due to the lack of a clear professional context, resulting in a widespread sense of alienation among students that "what is learned is useless."

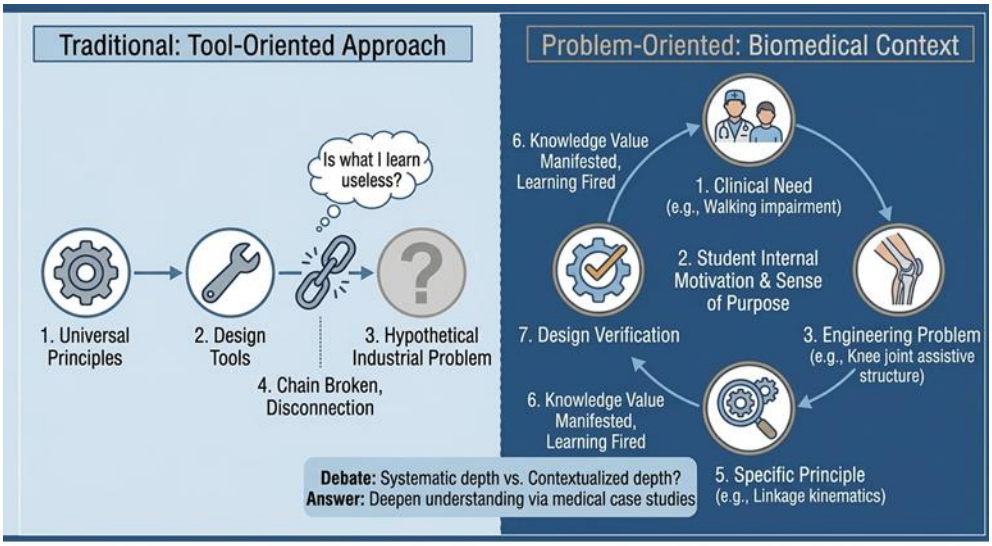

Figure 7. Core concept of the reform

In contrast, our problem-oriented approach reconstructs this teaching chain. First, it guides students to identify specific clinical needs, such as walking dysfunction. Next, it translates these needs into clear engineering problems. Finally, it introduces the specific mechanical principles required to solve the problem, ultimately leading to complete design verification. The design of chapters such as rehabilitation engineering and biomechanics is precisely the concrete practice of this reconstructive concept. The significant advantage of this pathway is that it explicates the applied value of abstract knowledge, thereby effectively stimulating students' intrinsic learning motivation and sense of purpose.

However, an ensuing controversy is whether this highly contextualized teaching method comes at the expense of students' systematic and universal understanding of fundamental engineering principles. We believe the key to success is achieving "profound theories explained in simple terms." The goal is not to reduce theoretical depth. Instead, real medical cases act as bridges to deep principles. This prompts students to autonomously deepen their understanding of complex engineering principles while actively solving clinical problems.

3.2. Practical Challenges and Implementation Pathways

Putting the curriculum reform blueprint into practice mainly faces three challenges, the first of which is the reconstruction of faculty capabilities. Currently, teachers capable of integrating mechanical principles with clinical medicine are extremely scarce, constituting the biggest bottleneck in advancing the reform. Therefore, one cannot solely rely on replacing teachers; rather, efforts should be focused on building interdisciplinary teaching teams. For example, teachers with mechanical backgrounds can be responsible for theoretical lectures, while clinicians and rehabilitation therapists are invited to participate in case discussions. Furthermore, existing teachers should be encouraged to undertake short-term practical training in hospitals or enterprises to bridge the gap between knowledge and application scenarios.

Secondly, the development of teaching resources is also crucial. The reform plan heavily relies on high-quality clinical case databases, professional simulation software, advanced experimental equipment

(such as motion capture systems and 3D printers), and stable clinical practice bases, all of which require continuous and dedicated investment from institutions. Given this, a feasible strategy is "phased construction and resource sharing," which means prioritizing the development of several core demonstrative cases and experimental modules, while actively co-building practice platforms with medical schools and affiliated hospitals to alleviate resource pressure.

Finally, the reform of the evaluation system is equally unavoidable. Traditional written exams have limited effectiveness in assessing students' comprehensive abilities to solve complex, open-ended medical design problems; thus, the new evaluation methods must shift towards process-oriented and diversified approaches. This entails incorporating design reports, prototype works, simulation analysis reports, and even usability test reports based on real user scenarios into the evaluation scope, which inevitably requires teachers to invest more effort in full-process guidance and assessment.

To actively address these challenges and translate the theoretical framework into practice, our university (University of Shanghai for Science and Technology, USST) has established dedicated laboratories related to rehabilitation engineering. The university has explicitly designated specific teachers from these laboratories to be responsible for the aforementioned mechanical design courses. The contents and proposals presented in this paper are entirely derived from the firsthand teaching experiences and reflections of these teachers. Since the course content and lesson planning are completely determined by these instructors, the proposed curriculum reform is highly feasible and can be piloted as early as next semester. Specifically, we have formulated a concrete plan to officially pilot this reform at USST starting in the Fall semester of the 2026 academic year. This pilot program will utilize the existing laboratory resources and the newly designed problem-oriented modules to validate the effectiveness of the curriculum reconstruction and refine the teaching process.

3.3. Profound Impacts on Disciplinary Ecology and Talent Cultivation

The potential impact of this reform will extend beyond a single course, radiating to the entire BME disciplinary ecology. For students, it helps shape a clear professional identity, transforming them from cross-disciplinary learners with vague knowledge structures into goal-oriented professional engineers capable of solving specific medical problems, thereby building profound and solid professional skills. For majors and institutions, the reform will drive the formation of differentiated core competitiveness: different institutions can leverage their own strengths, under engineering or medical backgrounds, to develop distinctive directions such as intelligent surgical robots or high-performance rehabilitation assistive devices, thereby avoiding the dilemma of homogenization in program development. For the industry, the reform is expected to deliver talents who better meet demands and can quickly integrate into the R&D process. Graduates will not only master engineering skills but also deeply understand clinical logic, regulatory frameworks, and market realities, which will significantly shorten their adaptation period from campus to R&D positions, directly serving the strategic needs of a Healthy China.

4. Conclusion

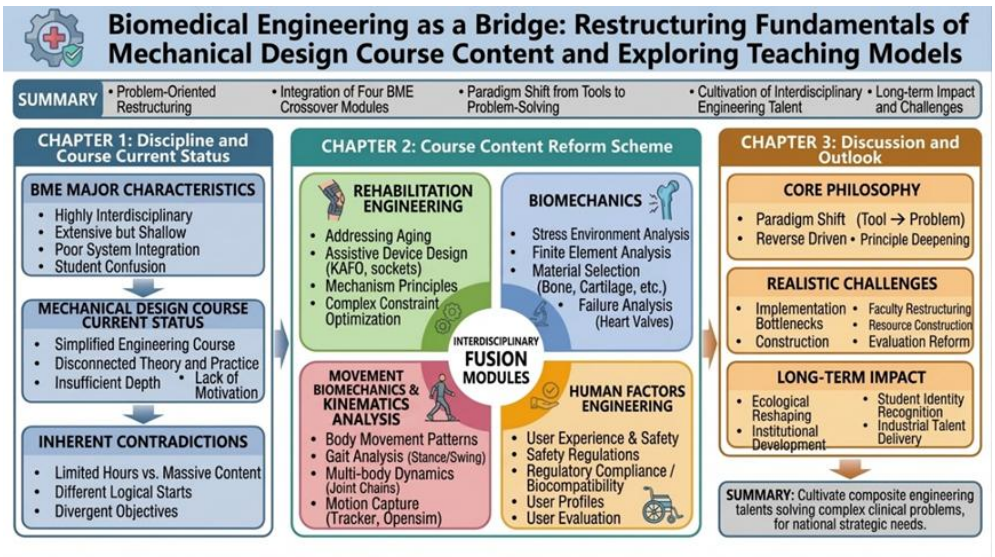

Figure 8. Summary of the paper's content

This paper systematically analyzes the root causes of the current "broad but not refined" curriculum status, specifically elucidates the core argument proposed in the abstract that "the logical starting point of Biomedical Engineering is different from that of traditional engineering," and demonstrates its complex manifestations in actual teaching. It explicitly points out two fundamental problems urgently needing reform: the knowledge anxiety of being broad but not deep at the major level; and the disconnect between learning and application, as well as the lack of depth, at the mechanical course level. It proposes a specific reform plan centered on four major medical-engineering interdisciplinary modules: "Rehabilitation Engineering," "Biomechanics," "Sports Biomechanics," and "Human Factors Engineering." These plans treat the human body and diseases as new constraints for mechanical design. By placing abstract principles (like gears and kinematics) under the umbrella of "designing for human health," this approach highlights the practice-oriented teaching goal. Traditional teaching moves from learning general principles to solving hypothetical problems, whereas the new plan follows "identifying clinical needs → translating into engineering problems → introducing and deepening required principles." This answers the fundamental question of "why reform is needed." By using real medical cases as "entry points," it guides students to actively construct and deepen their understanding of complex principles, rather than reducing theoretical depth. The greatest challenge is the lack of teachers who can integrate mechanics and medicine. The proposed pathway is to build interdisciplinary teaching teams (mechanical teachers + clinicians) and encourage teachers to undertake clinical practice training. Addressing the high reliance on case databases, simulation software, experimental equipment (e.g., 3D printing, motion capture), and clinical practice bases, it recommends phased construction and resource sharing. Traditional written exams cannot measure comprehensive design abilities; thus, there must be a shift towards process-oriented and diversified evaluations, such as grading based on design reports, prototype works, simulation analyses, and usability test reports. Finally, the profound impacts the reform may have on the discipline and industry are presented. For students, it helps shape a broad medical-engineering perspective alongside deep professional skills in a specific area, resolving the issue of a vague professional identity. For majors and institutions, it drives the formation of differentiated core competitiveness, encouraging different institutions to develop distinctive directions (such as surgical robots or rehabilitation assistive devices) based on their own strengths to avoid homogenization. For the industry, it delivers more ready-to-use talents, shortening the time graduates need to adapt to R&D positions, and directly serves relevant national strategic needs.

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REFERENCES

1. Zifan Che, Yue Zhang, Minhao Wu, et al. Bibliometric Analysis on the Development of Biomedical Engineering[J]. Science Focus, 2022, 17(05): 1-10.
2. Yuqing Wang. The Survey of Biomechanical Engineering Research[J]. Engineering Science, 2005(11): 16-20.
3. Lijun Hao, Geng Zhu, Xiupin Wu, et al. Construction of biomedical engineering specialty courses integrating “two natures and one degree” concepts:Taking “Principle and Application of Medical Instruments” as an example[J]. China Medical Education Technology, 2022, 36(02): 175-180.
4. Wanting Zheng, Liangliang Chen, Xin Zhang, et al. Exploration and Research on the Talent Cultivation Model for Biomedical Engineering under the Background of Emerging Engineering Education[J]. China Higher Medical Education, 2025(07): 1-3+6.

5. Tyler S. Love, Joshua P. Cysyk, Anilchandra Attaluri, et al. Examining Science and Technology/Engineering Educators' Views of Teaching Biomedical Concepts Through Physical Computing[J]. Journal of Science Education and Technology, 2022, 32: 96-110.
6. University of Electronic Science and Technology of China. Biomedical Engineering (Medical-Engineering Intersection, Information Biology and Genetic Engineering)[EB/OL], 2025. https://zs.uestc.edu.cn/view/141.html?code=21&tid=14011.
7. Zhejiang University. The first session of Shengyi's "Career Express" - a graduate employment sharing session was successfully held[EB/OL], 2025. http://www.cbeis.zju.edu.cn/2025/0313/c63880a3027003/page.htm.
8. Tao Li. The college carried out internship research and visit work for the Biomedical Engineering major in five hospitals in Hangzhou[EB/OL], 2025. https://wzeye.cn/edu/news2/show-64947.html.
9. Southern Medical University. Notice on the Internship Arrangement for Undergraduate and Postgraduate Students of the Class of 2026[EB/OL], 2025. https://portal.smu.edu.cn/swyxgcxy/info/1138/12737.htm.
10. Huijun Xue, Yang Zhang, Xiao Yu, et al. Research on the Project Teaching Reform of Circuit Principle Course of Biomedical Engineering Major[J]. EDUCATION AND TEACHING FORUM, 2022, No.567(16): 56-59.
11. Technology Queensland University of. EGH435 Modelling and Simulation for Medical Engineers[EB], 2024.
12. Lingyue Kong, Jing Zhang, Dongmu Tian, et al. The Wear on a Novel Motion Mode Hinged Knee Prosthesis: A Finite Element Analysis[J]. Journal of Medical Biomechanics, 2023, 38(01): 97-103.
13. Yu Qian, Xinwei Li, Bingze He, et al. Static Finite Element Analysis on Hip Disarticulation Prosthesis Socket-Residual Limb in Stance Phase[J]. Journal of Medical Biomechanics, 2021, 36(06): 923-928.
14. Qinying Song. A CiteSpace-Based Bibliometric Analysis of Domestic and International Research on Rehabilitation Assistive Devices[J]. China Social Welfare, 2025, No.647(05): 24-41.
15. Ying Zhu. Design and Development of a Lightweight Stiffness-Tunable Ankle-Foot Orthosis[D]. Donghua University, 2025.
16. Minghui Wang, Qingjun Nong, Yu Qian, Yinhui Huang, Yinhao Wang, Hongliu Yu, Design of Adjustable Frame-Type Prosthetic Socket for Lower Limb, IRBM, 2023.
17. Yingnan Hu, Wanwan Shi, Datao Wang. Blood cells and the occurrence and progression of osteoporosis: potential of biomarkers and emergingtherapeutic strategies[J]. Chinese Journal of Tissue Engineering Research, 2025.
18. Taieb Messaad, Abdelghani Baltach, Mohammed El Sallah Zagane, et al. Biomechanical analysis of prosthetic liners in transfemoral amputees using finite element modeling[J]. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 2025, 47.
19. Sergio Barroso Rosa, Kaushik Hazratwala, Matthew P. R. Wilkinson. Mismatch between trochlear coronal alignment of arthritic knees and currently available prosthesis: a morphological analysis of 4116 knees and 45 implant designs[J]. Knee Surgery, Sports Traumatology, Arthroscopy, 2023, 31: 3116-3123.
20. M.Grigioni, C.Daniele, G.D"Avenio, et al. Wear patterns from fatigue life testing of a prosthetic heart valve[Z]: 1-6.
21. Rahul Talukdar, Ceby Saviour, Kaustubh Tiwarekar. Bone Remodeling Around Solidand Porous Interbody Cages in the Lumbar Spine[Z]: 1-12.
22. Andres R. Perez, Carlo Coladonato, Rahul Muchintala, et al. A systematic review of the biomechanical properties of suture materials used in orthopaedics[J]. Journal of Orthopaedics, 2024, 51: 122-129.
23. David G.Lloyd, Ilse Jonkers, Scott L.Delp, et al. The History and Future of Neuromusculoskeletal Biomechanics[Z]: 1-11.
24. Weilin Cai, Zhengyu Wang, Yi Wang, et al. Comfort perception on wheelchair lock actuating rod position in younger and older adults[J]. International Journal of Industrial Ergonomics, 2025, 107: 103731.
25. Qihao Zhou, Dixin Liu. Research on Family Medical Bed Design Based on Multimodal Data Fusion[J]. Art & Design, 2024, No.378(10): 142-144.