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Research on the Training Path of Medical-Engineering Interdisciplinary Talents Empowered by Artificial Intelligence

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Abstract: As a core component of national strategies, interdisciplinary integration is critical to cultivating innovative interdisciplinary talents and promoting scientific and technological progress. Medical-engineering talent training has become a key focus of higher education reform and has been widely explored by domestic universities. However, its systematic construction still faces prominent problems, including insufficient top-level curriculum design, underdeveloped industry-education integration platforms, inadequate faculty collaboration mechanisms, and incomplete diversified talent evaluation systems. By reviewing typical domestic and foreign medical-engineering talent training models and integrating cutting-edge artificial intelligence technologies, this study explores innovative mechanisms and practical training paths for the intelligent era. It proposes four optimization approaches: intelligent teaching content generation driven by multimodal large models, practical teaching innovation supported by AI virtual simulation and intelligent design, personalized teaching realized through large model-based academic diagnosis and adaptive learning, and an integrated talent evaluation system constructed via multi-dimensional data and intelligent algorithms. This research provides theoretical references and practical guidance for building a high-level medical-engineering interdisciplinary talent training system in Chinese universities.

Keywords: Medical-engineering interdiscipline; Artificial intelligence; Large model; Talent training; New medical discipline; Intelligent medical education

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1. Introduction

The training of medical-engineering interdisciplinary talents is a core topic and strategic direction of higher education reform in the new era, and its systematic implementation at the undergraduate stage delivers multiple strategic values. First, in terms of talent cultivation, it serves as a vital approach to foster interdisciplinary talents with integrated multidisciplinary knowledge and innovative thinking. Second, for scientific and technological innovation, it provides talent support to break through technical bottlenecks in the healthcare sector. Third, from the perspective of national strategy, it directly meets major strategic demands, including the Healthy China 2030 Initiative and the innovation-driven development strategy [1].

Currently, disruptive technologies represented by artificial intelligence, big data and biomedical engineering have advanced rapidly, bringing unprecedented changes to the diagnosis and treatment paradigm in healthcare. The industry has witnessed a sharp rise in demand for interdisciplinary talents who possess both professional medical expertise and engineering practical capabilities [2]. Nevertheless, the traditional single-discipline-oriented education model has obvious limitations in curriculum design, training mechanisms and practical platforms, failing to satisfy the demand for such compound talents. As a critical stage for professional talent development, undergraduate education is a golden period for students to accumulate academic knowledge and gain practical experience, making it ideal for cultivating interdisciplinary competencies.

Building an education system featuring in-depth integration of medicine and engineering can systematically reorganize students' knowledge structure, integrate innovative thinking modes and jointly improve their practical abilities, enabling them to apply engineering technologies to solve medical problems. This training model can effectively enhance talents' adaptability to the future development of medical technology and sustainably supply qualified professionals for the innovative growth of China's healthcare industry. Therefore, undergraduate education for medical-engineering interdisciplinarity is of great significance to interdisciplinary talent training.

First, undergraduate medical-engineering education helps break disciplinary barriers and promote knowledge integration [3]. The integration of medicine and engineering covers cutting-edge fields such as biomedical engineering, intelligent medical imaging, medical robots and wearable medical devices, requiring students to master interdisciplinary knowledge at the undergraduate stage. This early interdisciplinary training mode effectively avoids the problem of fragmented knowledge structure in traditional medical or engineering education, and equips students with a broader academic vision and stronger innovation capacity.

Second, it strengthens students' practical abilities and boosts collaborative education among enterprises, universities and research institutes [4]. The combination of medicine and engineering relies not only on the integration of theoretical knowledge, but also on robust practical platforms. Such platforms help students translate theories into practical skills, facilitate collaborative innovation among universities, hospitals and enterprises, and accelerate the transformation of medical technological achievements.

Third, undergraduate medical-engineering education is a key measure to respond to national strategic needs [5]. The implementation of the Healthy China strategy calls for stronger independent innovation capacity in the medical industry. At present, China still heavily relies on imports for high-end medical devices, and breakthroughs in core technologies urgently require support from medical-engineering interdisciplinary talents. As the starting point of talent cultivation, systematic medical-engineering education at the undergraduate level can deliver more innovative interdisciplinary talents with independent research and development capabilities for the country.

Finally, it optimizes the talent training system and enhances international competitiveness. Global medical education is undergoing profound transformations. Top universities in Europe and America, such as Harvard University and the Massachusetts Institute of Technology (MIT), have taken the lead in launching medical-engineering interdisciplinary programs. The MD+PhD dual doctoral programs launched by Chinese universities align with international advanced models. Interdisciplinary training at the undergraduate level shortens the growth cycle of high-end talents [6]. In addition, it facilitates international academic exchanges. This internationally compatible training mode not only improves the competitiveness of China's medical-engineering talents, but also contributes Chinese solutions to global medical technological innovation.

In summary, undergraduate medical-engineering education plays an irreplaceable role in disciplinary integration, practical ability cultivation, national strategy implementation and international competitiveness improvement [7]. In the future, universities should further optimize interdisciplinary curriculum systems, strengthen collaborative platforms among universities, enterprises and hospitals, and improve the integrated undergraduate-postgraduate training mechanism, so as to cultivate more interdisciplinary talents leading medical technological innovation and provide solid support for the sustainable development of China's healthcare sector.

2. Current status and existing problems of medical-engineering interdisciplinary talent training at home and abroad

2.1. Current development worldwide

Medical-engineering interdisciplinary talent training has become a major direction of global higher education and technological innovation. Universities, research institutions and industrial communities worldwide are actively exploring diverse training models to address technical challenges and talent shortages in healthcare.

Internationally, European and American countries started earlier in medical-engineering education and have established relatively mature training systems. For instance, the MedTec School jointly launched by Università Humanitas and Politecnico di Milano in Italy adopts a six-year integrated bachelor-master program to train engineer-physicians with dual degrees in medicine and biomedical engineering. Adopting problem-oriented teaching and relying on advanced clinical simulation centers, the program integrates courses in automation, computer science and artificial organ technology. Its first cohort of graduates has made it a benchmark for medical-engineering education across Europe [8]. Top U.S. universities, including Harvard University and MIT, cultivate medical-engineering interdisciplinary talents via MD + PhD dual doctoral programs [9]. For example, the "Wearable Technology and Human Behavior" project at the MIT Media Lab combines engineering, art and medicine to drive the research and development of intelligent medical devices.

By comparison, medical-engineering interdisciplinary talent training in China started later, yet has developed rapidly in recent years with increasing policy support. The Ministry of Education has emphasized the importance of medical-engineering integration in the construction of Double First-Class universities and the Four New Disciplines initiative (Emerging Engineering, New Medical Science, Modern Agriculture and New Liberal Arts), and encouraged universities to explore innovative training models.

In 2025, Shanghai Jiao Tong University launched China's first 4 + 4 + X MD + PhD dual doctoral program for medical-engineering interdisciplinarity. Integrating cutting-edge fields such as artificial intelligence, biomaterials and big data, the program aims to train physician-scientists and physician-engineers capable of solving medical problems and leading technological transformations. Qilu Hospital of Shandong University adopts a model of medical-engineering integration, industry-education collaboration and joint talent cultivation, and establishes a dual-supervisor system with Fujian Cancer Hospital to train postgraduates to solve real clinical problems, such as optimizing AI-assisted CT image segmentation technology. Qingdao University has built an integrated undergraduate-postgraduate training system featuring three-dimensional collaboration. Supported by national first-class courses and university-enterprise joint laboratories, it promotes in-depth integration between medicine and engineering.

Moreover, the first batch of medical-engineering postgraduates jointly trained by Fuzhou University and Fujian Cancer Hospital have successfully graduated. Their research focuses on the application of artificial intelligence in oncological image analysis, embodying the philosophy of deriving problems from clinical practice and translating achievements back to clinical application. In terms of curriculum construction, Chongqing Medical University took the lead in compiling the first national planned textbooks for the major of Intelligent Medical Engineering, namely "Medical Big Data Technology and Medical Natural Language Processing." Focusing on multi-modal medical data management and intelligent analysis, these textbooks support the cultivation of interdisciplinary talents with solid medical knowledge, proficient technical skills and strong innovation capabilities.

Overall, China has formed a collaborative education pattern involving universities, hospitals and enterprises. Nevertheless, disciplinary barriers, fragmented curricula and insufficient industry-university-research cooperation still need to be further addressed to meet future challenges in healthcare.

2.2. Major problems in undergraduate medical-engineering interdisciplinary education

As an important approach to cultivating innovative interdisciplinary talents, undergraduate medical-engineering education still faces multiple challenges, which are summarized into five major aspects in **Figure 1**.

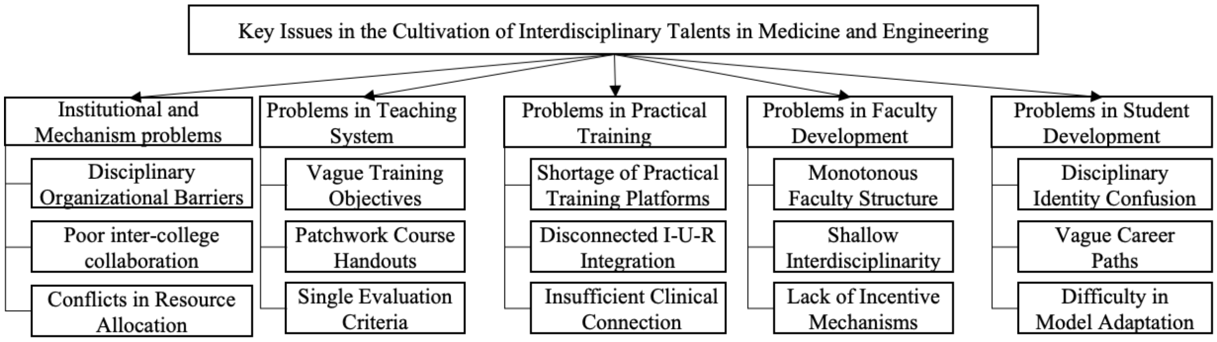

Figure 1. Major problems in medical-engineering interdisciplinary talent training.

(1) Disciplinary barriers and institutional obstacles

Promoting medical-engineering education in Chinese undergraduate universities is severely hindered by disciplinary barriers and defective organizational mechanisms. The traditional vertical hierarchical management system of university-school-department makes it difficult to share resources between medicine and engineering. Most interdisciplinary organizations exist only in name, with part-time faculty and no unified management [10]. For example, some medical-engineering laboratories are still managed under separate disciplines, and equipment access is restricted by departmental affiliation, leading to repeated resource allocation and low utilization efficiency.

In terms of operation, many faculties hold concurrent posts in interdisciplinary programs but take no corresponding responsibilities. Their performance assessment still belongs to their original disciplines, resulting in limited time and energy devoted to interdisciplinary work [11]. In addition, training objectives and service scopes are not clearly defined. Some universities launch related majors blindly without systematic planning based on industrial demands. These structural obstacles greatly restrict interdisciplinary resource sharing and students' innovative ability, and require institutional reform and evaluation system optimization to break through.

(2) Ambiguous training objectives and curriculum systems

Training objectives and curriculum design are not well-defined in current undergraduate medical-engineering education in China. Many universities fail to set clear positioning for relevant majors, and some launch programs blindly without demand-oriented systematic planning, leading to vague training orientations. For instance, although majors like Intelligent Medical Engineering advocate medical-engineering integration, their training objectives still follow the framework of traditional biomedical engineering, failing to fully integrate emerging technologies such as artificial intelligence and big data [12].

In curriculum design, medical and engineering courses are simply combined rather than organically integrated [13]. Some majors for medical devices and equipment engineering adopt a modular stacking mode without establishing internal logical connections between interdisciplinary knowledge. Although core courses such as "Medical Big Data Technology" and "Medical Natural Language Processing" have supporting textbooks, unified national curriculum standards have yet to be established, resulting in inconsistent teaching content across universities. Furthermore, most courses focus merely on theoretical lectures, lacking case teaching based on real clinical scenarios. It is essential to clarify tiered and categorized training objectives and build dynamically adjusted curricula to keep pace with the rapid development of the healthcare industry.

(3) Deficient practical platforms and industry-university-research collaboration

The construction of practical platforms and collaborative mechanisms is far from sufficient in undergraduate medical-engineering education [14]. Separate disciplines, manage most interdisciplinary laboratories and equipment access is limited by departmental barriers, resulting in low resource sharing. Students rarely have access to authentic interdisciplinary practical experience due to isolated resources between biomedical engineering schools and clinical medical schools.

Cooperation between universities and enterprises mostly stays at the contractual level with shallow industrial participation. There is a prominent disconnection between clinical demands and engineering R&D, and a stable closed loop of demand-R&D-application among medical institutions, universities and enterprises has not been formed. The cooperation case between Xi'an Jiaotong University and Shanghai Institute of Medical Device Testing proves that only physical platforms, such as joint laboratories, can realize seamless connection between R&D and inspection. In the future, an integrated collaboration system covering industry, education, research, clinical practice and testing should be established. Guided by policies, joint platform construction and benefit sharing will help overcome the bottlenecks of weak practical training and insufficient collaboration.

(4) Imperfect faculty team and evaluation system

The development of faculty teams and evaluation mechanisms remains a prominent challenge [15]. Most interdisciplinary teachers hold concurrent positions without corresponding accountability, as their personnel affiliation and performance appraisal still belong to their original disciplines, which reduces their devotion to interdisciplinary work.

The current assessment system is oriented to traditional disciplines, lacking diversified evaluation criteria tailored for medical-engineering interdisciplinarity. Teachers in the intelligent medical research center of a Double First-Class university reported that their interdisciplinary research achievements are poorly recognized in traditional discipline evaluations, hindering professional title promotion. In addition, there is no sound training system for interdisciplinary teachers, causing their professional knowledge to lag behind industrial updates. Poor communication and collaboration between teachers of different disciplines also impede the implementation of medical-engineering education. Systematic reforms in personnel management, performance appraisal and career development are required to guarantee sustainable faculty support.

(5) Weak disciplinary identity and unclear career paths for students

Students in medical-engineering programs face dual challenges: weak disciplinary identity and ambiguous career development paths [16]. Medicine and engineering have vastly different knowledge systems, easily causing cognitive conflicts and a lack of sense of belonging among students. Students with engineering backgrounds need to spend extra time learning medical knowledge, while medical students often feel daunted by engineering technologies, resulting in low learning motivation.

In terms of career development, there is no standardized classification for jobs in medical engineering fields. Graduates often fall into an awkward situation where they are neither proficient enough in clinical medicine nor skilled in engineering. Besides, the industry has no unified evaluation standards for such compound talents, and the training system for interdisciplinary bridge talents who understand both clinical needs and core technologies is still immature, further confusing students' career planning. Targeted measures, including optimized curriculum connections, strengthened career guidance, and improved industrial certification, are needed to enhance students' disciplinary identity and broaden their career prospects.

To conclude, breakthroughs must be made in institutional reform, curriculum optimization, practical platform improvement, faculty evaluation innovation and career guidance for undergraduate medical-engineering education, so as to cultivate qualified interdisciplinary talents that meet national strategic demands.

3. Exploration of talent training paths for medical-engineering interdisciplinarity empowered by artificial intelligence

With the rapid advancement of artificial intelligence (AI), large models are being increasingly applied in the integrated fields of medicine and engineering, and are gradually being integrated into education systems. AI large models can empower the training of medical-engineering interdisciplinary talents in aspects including courseware development and teaching content innovation.

3.1. Teaching content innovation driven by multimodal large models

AI large models are profoundly transforming the courseware development mode for medical-engineering talent training, with their core value lying in enabling the intelligent, dynamic and personalized creation of teaching resources. Supported by three core technologies, Natural Language Processing (NLP), Computer Vision (CV), and Knowledge Graph (KG), large language models represented by GPT-4, Ernie, and DeepSeek boast outstanding semantic understanding and content generation capabilities. They can automatically extract key knowledge points from medical textbooks, clinical guidelines and cutting-edge literature to build structured teaching frameworks.

Notably, multimodal large models such as DALL·E3 and Stable Diffusion break the limitations of traditional courseware. They can intelligently generate high-fidelity medical images, 3D anatomical diagrams and dynamic principle demonstrations, visualizing abstract and complex medical-engineering knowledge.

In medical-engineering education, the automatic courseware generation system powered by AI large models follows an innovative workflow: intelligent knowledge extraction, dynamic content organization, and immersive rendering. First, large models conduct in-depth semantic analysis to identify core concepts and research advances from massive literature, eliminating the time-consuming manual sorting work. Second, leveraging powerful sequence modeling capabilities, they reorganize fragmented knowledge points into logically structured curricula complying with cognitive rules, and automatically generate supporting explanatory texts. Third, the system intelligently integrates texts, images, 3D models and interactive components. For instance, when teaching the navigation principles of intelligent surgical robots, the courseware can synchronously display mechanical simulation of instrument motion trajectories, visual analysis of algorithm decision-making, and augmented reality (AR) demonstration of real surgical scenarios.

This dynamic generation mode addresses the outdated courseware issue caused by faculty shortages, keeps teaching content aligned with disciplinary development, and provides strong support for cultivating interdisciplinary innovative talents.

3.2. Practical teaching assisted by AI large model technology

Practical teaching acts as a vital link connecting theoretical knowledge and engineering application in medical-engineering talent training. The adoption of AI large models brings disruptive changes to practical teaching, showing great potential in virtual simulation training, intelligent design and real-time interactive feedback.

(1) Highly simulated virtual surgical training system

Limited clinical resources, ethical risks and high operational costs restrict traditional medical practice. Large model-based virtual simulation systems can create highly realistic surgical environments. Combined with generative AI and physics engines, the systems dynamically simulate mechanical properties, tissue deformation and bleeding effects of different anatomical structures, allowing students to repeatedly practice complex operations such as laparoscopic and orthopedic surgery in virtual scenarios. Embedded with an intelligent tutor function, large language models analyze students' operation trajectories in real time, deliver voice guidance and generate personalized training reports to help students improve operational skills precisely.

(2) Intelligent design and testing of medical devices

In engineering practice for medical-engineering integration, large models accelerate the prototype development of medical devices. With multimodal inputs including texts of clinical demands, medical images, and biomechanical data, generative design models built on the Diffusion Model can automatically propose ergonomic device solutions and output 3D-printable models. Meanwhile, virtual testing platforms simulate the performance of devices in real physiological environments, such as the blood compatibility of stents and wear resistance of artificial joints, greatly shortening the research and development cycle. Through interactive design with large models, students can not only master engineering specifications but also foster clinically-demand-oriented innovative thinking.

(3) Dynamic clinical cases and interdisciplinary collaborative experiments

Large models can generate virtual dynamic cases based on real clinical data, such as cases of diabetic patients with progressive conditions. Students are required to formulate diagnosis and treatment plans by applying engineering technologies including wearable device data analysis and insulin pump control algorithms. For team collaboration, students with different academic backgrounds (medical students and engineering students) can complete interdisciplinary tasks such as surgical robot path planning and intelligent prosthetic signal processing via shared virtual laboratories built by large models. The system automatically evaluates the feasibility of solutions and puts forward optimization suggestions.

(4) Real-time feedback and adaptive learning

Dynamic responsiveness is a major advantage of large models. During practical training, every operation performed by students (e.g., suture tension and circuit design parameters) is analyzed in real time. The AR interface instantly marks errors such as excessive electrical stimulation intensity and recommends correction strategies. In addition, the system adjusts training difficulty adaptively according to students' performance. For example, shifting from simple appendectomy to precise resection of tumor edges to realize progressive personalized skill development.

3.3. Personalized teaching for talent training empowered by AI large models

In medical-engineering talent training, students have diverse academic backgrounds and varied learning abilities, which pose great challenges to traditional teaching modes. With intelligent assessment, dynamic content generation and customized learning path planning, AI large models facilitate the transformation of medical-engineering education into a personalized teaching model featuring tailored solutions for individual students.

(1) Student profiling and competency assessment

By analyzing multi-dimensional data, including pre-class test results, virtual experiment records, and literature reading preferences, large models build dynamically updated learner profiles. For students with clinical medicine backgrounds, the system automatically identifies weaknesses in engineering modeling capabilities; for engineering students, it focuses on strengthening their mastery of anatomy and medical norms. Diagnosis models based on the Transformer architecture track knowledge proficiency in real time and generate visual competency maps, laying a data foundation for personalized teaching.

(2) Adaptive teaching content generation

Relying on the content generation capability of LLMs, teaching content can be reconstructed instantly to meet individual learning needs. For visual learners, abstract algorithms are converted into interactive 3D flowcharts. For students with weak theoretical foundations, comparative cases are provided, such as a side-by-side demonstration of traditional surgical navigation and AI-enhanced navigation. For advanced learners, simplified interpretations of the latest research papers are delivered together with relevant engineering implementation cases.

(3) Intelligent tutoring and metacognition development

AI tutors integrated into teaching systems provide scenario-based guidance. In surgical robot operation training, they answer questions via natural language interaction and give explanations based on biomechanical principles. When students write course papers, the system automatically checks the logical rigor of literature citations and offers revision suggestions. It also designs personalized reflective questions to cultivate students' higher-order thinking skills.

3.4. Talent training evaluation empowered by AI large models

The current evaluation system for medical-engineering interdisciplinary talents faces three major dilemmas. First, evaluation methods are rigid. Over-reliance on standardized written examinations makes it hard to assess students' interdisciplinary integration capabilities effectively. Second, the evaluation process is fragmented. Theoretical assessment is separated from practical evaluation, failing to comprehensively examine the coordinated development of medical thinking and engineering competencies. Third, evaluation feedback is delayed. Traditional manual marking usually takes two to three weeks, which cannot guide timely learning improvement. These structural flaws severely undermine the quality of interdisciplinary innovative talent training.

Large AI models provide revolutionary solutions to the above problems. By establishing a three-tier evaluation framework of data collection, intelligent analysis, and dynamic optimization, intelligent and scientific evaluation for interdisciplinary talent training can be realized.

(1) Multi-dimensional evaluation data collection

Large models integrate data generated throughout students' theoretical learning, virtual experiments and project practice. Semantic analysis of assignments and exam papers enables a comprehensive assessment of knowledge mastery. Analysis of parameters such as force and precision from surgical simulators accurately evaluates practical operational skills. Analysis of the novelty and feasibility of project schemes assesses students' innovative capacity.

(2) Innovative intelligent evaluation methods

Deep learning models enable intelligent evaluation of medical-engineering students. For automatic scoring of practical operations, computer vision analyzes operation videos and detects millisecond-level deviations from expert standards. For innovative thinking assessment, LLMs score course papers from multiple dimensions, including clinical value and technical feasibility. For learning trajectory prediction, time-series models analyze learning data to give early warnings of potential competency deficiencies.

(3) Dynamic feedback and personalized improvement

Large model-driven evaluation systems form a closed-loop optimization mechanism and deliver instant feedback. In engineering design experiments, AI pinpoints errors and explains relevant medical principles. The system adapts learning paths and adjusts curriculum difficulty dynamically based on evaluation results. It also provides personalized career development suggestions and generates individual competency matching reports by combining the demands of clinical and engineering positions.

The introduction of AI large models into medical-engineering talent training effectively resolves problems such as resource constraints and single evaluation criteria in traditional education. It provides intelligent support for cultivating interdisciplinary talents with both clinical thinking and engineering innovation capabilities, and promotes the development of medical-engineering education toward precision, personalization and high efficiency.

5. Conclusion

Large AI models bring revolutionary impetus to talent training and drive a paradigm shift in medical education from standardized training to personalized development. By establishing a three-in-one intelligent training system featuring intelligent diagnosis, targeted recommendation, and adaptive learning, large model technology effectively breaks through core bottlenecks in traditional medical-engineering education, such as disciplinary barriers and homogenized training, and creates a genuine new paradigm for personalized talent cultivation.

With the in-depth integration of multimodal large models with extended reality, digital twin and other technologies, medical-engineering interdisciplinary talent training will step into a new era featuring higher intelligence, personalization and precision. It will not only cultivate interdisciplinary innovative talents who understand clinical demands and master engineering technologies for the Healthy China strategy, but also boost the coordinated development of medical service quality and medical technological innovation. This AI-driven educational transformation has reshaped the ecosystem of medical talent training and provided a referable model for educational innovation in other interdisciplinary fields.

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Disclosure statement

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