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Exploration on the Construction of a Virtual Teaching and Research Section in Cultivating Biomedical Engineering Excellent Talents

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Abstract: A virtual teaching and research section, unrestricted by time, space, or geographical boundaries, offers a solution to overcome the limitations of traditional physical teaching and research institutions. After the role of each party (i.e., university, medical enterprises, hospitals, medical regulatory authorities, and medical R&D institutes) in the virtual teaching and research section was introduced, the methods to address teaching challenges faced by department of biomedical engineering, a highly interdisciplinary major spanning biology, medicine, and engineering, was presented. Finally, outcomes that yielded since establishing this virtual section were also presented.

1. Introduction

Traditional department in colleges and universities serves as a fundamental unit, facilitating the execution of educational tasks, fostering faculty development in teaching, organizing academic research, and conducting various educational activities. The department is structured around a specific major and organizes its teaching and research division based on groups of courses that are either the same or similar. Essentially, it is a physical organization where educators who share a common goal collaborate on activities related to the development of a discipline, a major, or courses. However, these activities are confined by limitations such as participant availability, time, spatial constraints, and geographic location. As times evolve, traditional department is hard to address the demands for interdisciplinary, cross-major, and cross-industry professional talent development that the new era requires.

The rapid advancement of information technology has facilitated the development of innovative teaching and research methods, enabling the cross-temporal and spatial sharing of teaching resources and collaborative teaching processes. The establishment of a virtual teaching and research (VTR) section, which is not constrained by time, space, or geographic boundaries, offers a solution to the limitations inherent in traditional physical teaching and research organization [1-4]. The section consists of educators who excel in specific areas or share a common goal to address challenges. This

framework broadens the scope of teaching and research activities, making them more dynamic and accessible [5-10]. Major universities in China are actively exploring the creation of the VTR sections. In February 2022, the Ministry of Education announced the first batch of 439 pilot projects aimed at developing these virtual sections.

2. Problems

The main challenges faced by our major included, (1) The goals of the previous major curriculum system did not align with the demands of modern medical industries, hospitals, and medical regulatory authorities; (2) Biomedical engineering is an inherently interdisciplinary field, yet previous curriculum systems failed to address its diverse needs comprehensively; (3) The knowledge taught to students in the classroom was often difficult to apply in practical work settings. To address these issues, we proposed the establishment of a Virtual Teaching and Research (VTR) section.

3. Establishing a VTR Section

It is well-recognized that the discipline of biomedical engineering (BME) employs engineering methods to address medical problems, presenting pronounced interdisciplinary traits from science, engineering, and medicine. At our university, BME is designated as a key discipline in Shanghai and features a comprehensive talent training system spanning undergraduate, master's, and Ph.D. levels. Graduates at all levels are highly regarded and trusted by employers for their robust foundation in natural sciences and strong practical engineering skills.

The VTR section in our BME major comprises five parties: our university, medical enterprises, hospitals, medical regulatory authorities, and medical R&D institutes, as shown in Figure 1. The curriculums marked in blue are proposed and lectured by the corresponding party.

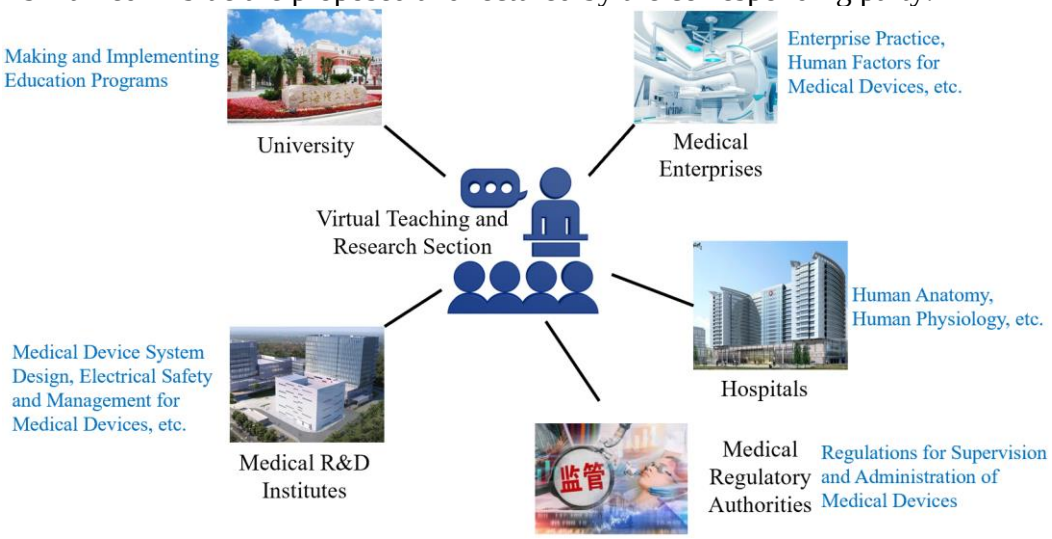

Figure 1: Framework of the five parties VTR section

The VTR section, composed of five collaborating parties, works jointly to cultivate outstanding talents comprehensively and throughout the entire educational process. In collaboration with medical enterprises, we have established an industrial college and nine joint laboratories on campus; Partnering with hospitals, we have created over 30 medical internship bases under contract; Working with medical regulatory authorities, we have developed a curriculum system that aligns with the registration, production, operation, use, and recall processes of medical devices. And, in cooperation with medical R&D institutes, we have set up a specialized and comprehensive training program

tailored to meet industry needs.

The VTR section is tasked with several key functions,

(1) to facilitate communication among all parties involved, enhance cooperation, and continuously expand and enrich the scope of the VTR section;

(2) to develop and refine the management system of the VTR section;

(3) to coordinate the arrangement of students who meet specific criteria for practice, gather feedback on the quality of teaching, and systematically collect, organize, and archive relevant documentation.

(4) Cooperate with the mentors from each party to implement and manage the talent training schemes and plans.

3.1. Role of the University

The university serves as the primary entity responsible for conducting educational activities, with the department of BME overseeing the quality of talent cultivation. Under the guidance and supervision of the university's Academic Affairs Office, the department implements training plans using various teaching methods and approaches to achieve its talent cultivation objectives. These plans are dynamically adjusted in response to industry developments, societal needs, and the status of the teaching staff. The establishment of a VTR section aims to further enhance the cultivation of outstanding talents and improve the overall quality of education.

3.2. Role of Medical Enterprises

Medical enterprises primarily encompass a range of medical device companies, which include those specializing in research and development, production, and sales. The demand for skilled professionals within these companies drives universities to establish relevant majors and provides a significant employment pathway for graduates. As the industry evolves, there is an increasing demand for high-quality medical device talents. Notable medical enterprises participating in the VTR section include Draeger Medical Equipment (Shanghai) Co., Ltd., Fuji Film (China) Investment Co., Ltd., Shanghai Aohua Photoelectricity Endoscope Co., Ltd., Shanghai MicroPort Medical (Group) Co., Ltd, etc.

To meet the needs of enterprises, we offer courses such as enterprise practice, human factors engineering for medical devices, biomedical electronics, etc.

3.3. Role of Hospitals

Hospitals are critical environments for patient treatment and care, housing a wide array of medical devices across various departments such as clinical laboratories, imaging, and dentistry. The operation of these devices often relies on principles from optics, mechanics, electronics, communications, and materials science, requiring a multidisciplinary approach. The curriculums offered by the department of BME reflect the applications found in hospital settings and stays updated with the latest advancements in medical device technology. Hospitals not only serve as key places for practical internships but also as potential future workplaces for students, particularly in equipment-focused roles. The hospitals currently involved in the VTR section include Xinhua Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Zhongshan Hospital Affiliated to Fudan University, Shuguang Hospital affiliated to Shanghai University of Traditional Chinese Medicine, and Shanghai Children's Medical Center.

In the BME educational programs, we invite excellent doctors from hospitals to teach courses like human anatomy, human physiology, etc.

3.4. Role of Medical Regulatory Authorities

The medical device management department is a specialized agency responsible for supervising, managing, and monitoring medical devices. Its responsibility is to ensure the safety, effectiveness, and compliance of medical devices, and to safeguard the health and safety of the public, mainly including: (1) registration and approval of medical devices; (2) supervision and inspection of medical devices; (3) market supervision of medical devices; (4) monitoring and reporting of adverse events of medical devices; (5) promotion of medical device safety education and awareness, etc. The medical regulatory authorities in the VTR section include National Medical Products Administration (NMPA), Yangtze River Delta Center for Medical Device Evaluation and Inspection of NMPA, etc.

In order to meet needs from the medical regulatory aothorities, we offer courses like regulations for supervision and administration of medical devices.

3.5. Role of Medical R&D Institutes

Medical device research and development (R&D) institutes represent the cutting-edge in medical device innovation and are hubs for high-tech talent. These institutes are dedicated to the development of medical devices aimed at diagnosing, preventing, monitoring, treating, or alleviating diseases. A notable example of such an institute is the Shanghai Institute of Medical Device Testing.

Targeting the needs of medical R&D institutes, we offer courses like medical device system design, electrical safety and management for medical devices, biomedical sensing and measurement, etc.

4. Methods to Solve Teaching Problems

Based upon the VTR section, several methods are employed to address teaching challenges in our BME major, including,

(1) Building an open talent training mode

We have established a long-term operational mechanism for university-enterprise cooperation. This involves inviting enterprises to participate in teaching, appointing part-time industry teachers, updating teaching content, constructing internship and training bases, promoting student employment, and employing various strategies to foster deep integration among the five parties in the VTR section. These collaborative efforts aim to seamlessly blend academic and practical experiences, enhancing the educational and professional outcomes for our students.

(2) Strengthening medical engineering

Based on the existing resources of our BME major, including our teaching staff, courses, and experimental facilities, we have deepened professional development and reform efforts. This includes strengthening partnerships with renowned domestic and international enterprises such as the China Association for Medical Devices Industry, Philips Healthcare Company, Siemens Healthcare Company, and Microport Company. We've also enhanced collaboration with clinical departments in 3A grade hospitals. These efforts are designed to closely align our curriculums and research initiatives with the specific needs of the medical industry, leveraging our professional strengths to meet these demands.

(3) Offering designed experiments

We have developed an experimental curriculum system designed to cultivate engineering and innovative talents in line with the evolving needs of the medical device industry. This system thoughtfully balances the ratio of experimental courses and hours between on-campus experiments and off-campus internships or training at enterprises and hospitals. By strengthening off-campus internships and deepening practical experiences in these settings, we aim to provide our students with the hands-on skills and real-world knowledge necessary to excel in their future careers.

(4) Implementing a dual leader system

We have implemented a dual leader system, comprising a campus professional leader and an enterprise professional leader, to maximize the integration of university and enterprise resources. This system ensures that the professional talent training program is co-supervised by both leaders, each leveraging their unique strengths. This collaborative approach effectively overcomes the temporal and spatial barriers typically associated with university-enterprise cooperation within the VTR section, enhancing the effectiveness and reach of our educational initiatives.

(5) Jointly promoting student employment

The employment outcomes of our students serve as a crucial measure of the success of our training programs. To effectively guide students in their career pursuits, the VTR section collaboratively provides employment guidance. We invite distinguished alumni and industry professionals from relevant enterprises to deliver expert presentations to our students. This approach not only informs students about career opportunities but also equips them with the necessary insights to navigate the job market successfully.

5. Outcomes after Building the VTR Section

Since the establishment of the VTR section, numerous positive outcomes have been realized, as shown in Figure 2.

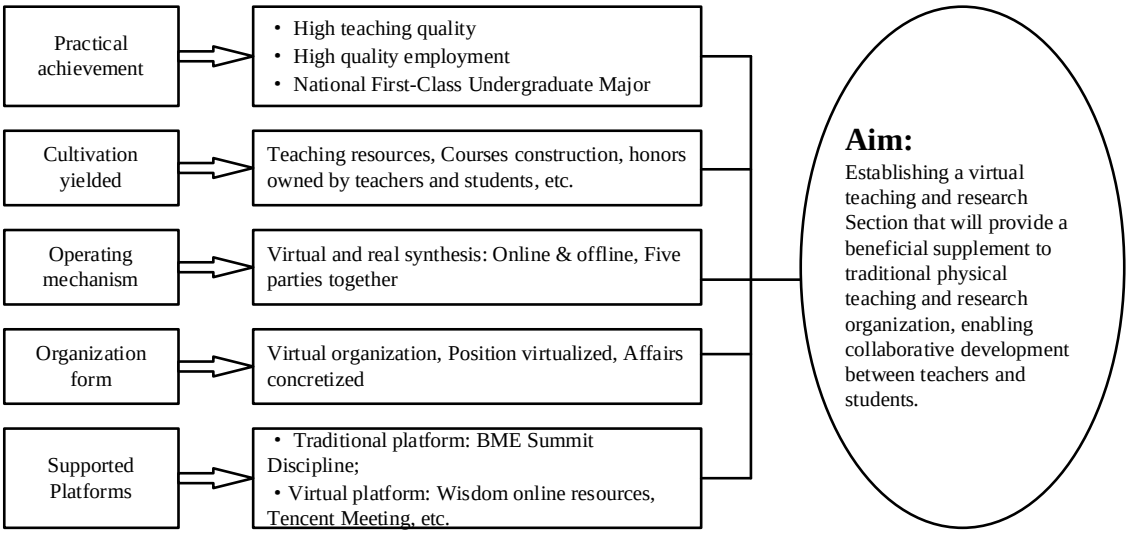

Figure 2: Outcomes after building the VTR section

Main outcomes include,

(1) Course construction. Through collaborative research involving the five parties, significant advancements in course design, standards, resources, and textbook development have been achieved in the BME major, (i) in the past five years, teachers in this major have consistently won either the first or second prize of the Excellent Course Teaching Award from our university every year. This achievement underscores the dedication and effectiveness of our faculty in delivering high-quality education. Additionally, a series of professional core courses have been established, further enriching the academic offerings of our program; (ii) course resources have been seamlessly integrated, facilitating a cohesive learning experience for students. This integration has not only improved access to educational materials but also enhanced our social service capabilities by 30%; (iii) the number of key and first-class courses has grown by 20%, enriching the curriculums and offering students a broader range of high-quality academic opportunities; (iv) three provincial and ministerial-level key teaching reform and curriculum construction projects have been successfully approved, signifying

recognition of our innovative educational initiatives at a higher administrative level.

Figure 3 illustrates the main courses in our BME major, categorized into different levels.

· **Basic Courses:** mathematics, physics, chemistry, English, humanistic literacy, and scientific writing

Professional Basic Courses: medical fundamentals, computer science, electronic information, and mechanical design

Professional Core Courses: principles of medical devices, design of medical instruments, biomedical materials, medical device testing and evaluation

Advances Courses: R&D of medical devices, medical engineering project management, medical information processing, and supervision and administration of medical devices.

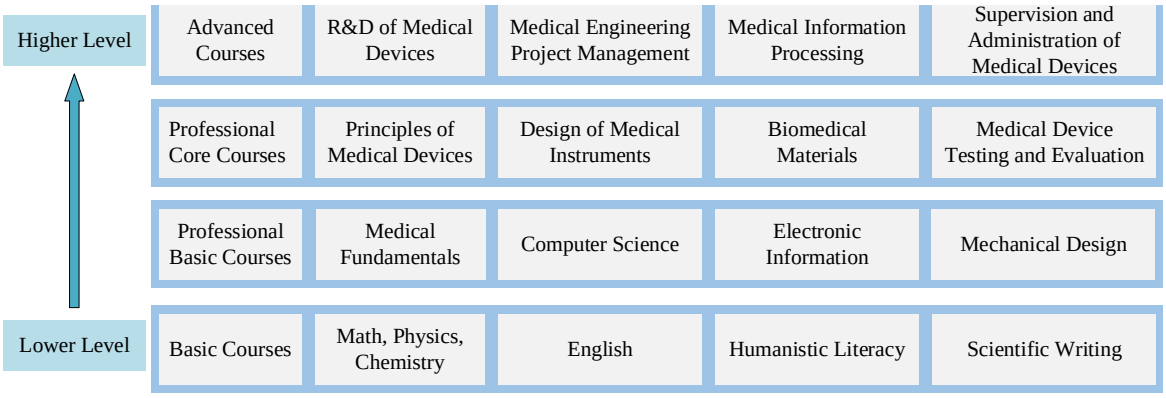

Figure 3: The courses in the BME major from different levels

(2) Higher enrollment rate. Figure 4 displays the proportion of our graduates who were admitted through the postgraduate entrance examination over the past four years. In 2020, the enrollment rate in our major was below the national average. However, in 2021 and 2022, it aligned closely with the national enrollment rate. Notably, in 2023, following the implementation of the VTR section, our enrollment rate significantly exceeded the national average, demonstrating the positive impact of our collaborative educational enhancements.

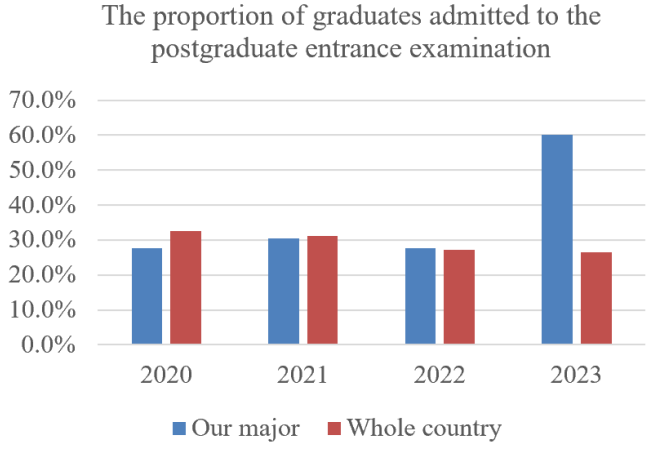

Figure 4: Enrollment rate in the past four years

(3) Competition awards. Under the collaborative framework of the five-party VTR section, we have actively organized students to participate in various skill competitions hosted by industries, the teaching guidance committee, and the Chinese Society of Biomedical Engineering, among others. These activities are aimed at enhancing students' practical skills and fostering a spirit of teamwork. Over the past three years, our faculty have mentored students on 12 national-level innovation and

entrepreneurship projects and numerous national competition projects, as well as 39 projects at the Shanghai municipal level. As a result of these efforts, fifteen student teams have garnered awards in various national and provincial-level competitions.

(4) Practice and training bases. (i) We collaborated with enterprises to establish an industrial college and develop 9 joint laboratories on campus; (ii) We partnered with hospitals and secured contracts with over 30 medical internship bases; (iii) We collaborated with regulatory authorities to develop a curriculum system aligned with the registration, production, operation, use, and recall processes of medical devices; (iv) We collaborated with medical research and development institutes to create specialized and comprehensive training programs tailored to meet industry needs.

(5) Other outcomes. (i) We partnered with 13 3A grade hospitals in Shanghai on 47 cross-disciplinary projects, engaging nearly 200 undergraduate students and enhancing their innovative research and development capabilities in medical device products; (ii) The employment rate of professional talents has increased by over 15%; (iii) The employment rate in well-known companies, 3A grade hospitals, and government drug regulatory departments in the medical device industry has increased by approximately 20%.

Acknowledgements

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