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Integrating Industry, Teaching and Research for Innovations on Postgraduates Education: Professional Degree Graduates in Chemical Engineering

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Abstract: To build the new disciplines of novel engineering and technologies for sustainable development, high education should be targeted to culture students in high-demanding fields. In the field of biotechnology, based on research projects, we have built a platform for biomedicine crossed with chemistry, physics, materials, electronic etc. In this paper, based on the traditional chemical engineering industry, education is targeted to be merged well with scientific research. To culture multidisciplinary students and experts, based on the modern education concepts such as "people-oriented", "comprehensive development" and "student development-centered", it is aimed at building a team of supervisors from interdisciplinary postgraduate supervisory groups, consolidating the fundamental knowledge, and enhancing the ability to use the skills and knowledge. It is proposed to make a multidimensional education system that includes the innovations in the education modes, contents, and methodologies, to make progress originally for multidisciplinary postgraduate training system.

Keywords: Modern Engineering Disciplines; Interdisciplinary Subjects; High Education; Postgraduates; Industry-Teaching-Research Cross

1. Introduction

The sustainable development of society and the pursuit of high-quality living rely on continuous innovation, breakthroughs, and advancements in science and technology. The foundation of such innovation lies in the interdisciplinary integration of technologies and knowledge, as well as the education and training of high quality, crossed interdisciplinary professionals [1]. As the leading force in education in talented human resources, universities should enhance the development strategies, management systems, and focus on training high-level interdisciplinary talents, in order to contribute to the advancement of emerging industries, leading the science and technology within specific fields, and the resolution of critical technological bottlenecks. [2]

The integration of interdisciplinary fields drives the reform of traditional industries and the emergence of novel technologies. For example, the merge of nanotechnology and biomedicine has led to the development of new antibacterial and anticancer drugs, [3, 4] functional medical devices etc.[5] Similarly, the integration of medicine with electronic information has created comprehensive diagnostic and treatment platforms. As biomedicine merges with fields such as nanotechnology, chemistry, chemical engineering, physical sciences, new materials, and electronics, barriers between disciplines are gradually breaking down. Consequently, it is urgent to explore innovative educational concepts and models to train interdisciplinary talents for high education.[6-8]

Both domestic and international universities have actively explored approaches to cultivating high-quality interdisciplinary talents. Stanford university, for example, has established a mature system for training interdisciplinary postgraduate students, benefiting from its early initiation in this area.[9] For example, the training philosophy in Stanford is to emphasize on "cutting-edge scientific and technological research" and "solving complex societal problems." The lectures and courses combine "compulsory and selective" as well as "fundamental and advanced" types, driven by student interests and supported by funding, platforms, human resources, and institutional guarantees. Such model is representative and has been referenced by universities in China. For instance, Lu and Wang in the College of Chemical Engineering at Harbin Institute of Technology proposed a "trinity and multidimensional integration" model for training under the "Grand Chemistry" approach[10], which emphasizes "precise coupling" between disciplines, aims to establish a dynamic knowledge system, and integrates major theoretical and practical platform to guide learning and innovation.

Professional postgraduate students are trained to meet the practical needs of specific industries or professions, with a growing proportion in the entire postgraduate population. Master programs for engineering aim to train advanced professionals with solid theoretical foundations and extensive knowledge and skills in chemical engineering, capable of solving complicated engineering problems with modern techniques. These students are expected to independently take charge of engineering technology or management roles. [11, 12]

However, under the background of new engineering disciplines, further exploration and innovation are needed in developing training models to produce graduates with strong comprehensive qualities who can quickly adapt to industrial demands. Taking postgraduate students in chemical engineering and medicine as an example, students must acquire interdisciplinary knowledge and skills encompassing chemistry, biomedicine, and engineering fundamentals, and should be able to apply such knowledge to solve practical issues in medicine and healthcare. Furthermore, students should be able to conduct research in medical technology, to carry out disease-oriented interdisciplinary studies, including innovations in medical devices, imaging technologies, and therapy innovations. Additionally, students should possess problem-solving skills for designing and improving medical equipment, developing new diagnostic methods, and optimizing therapeutic strategies. Professional qualities such as communication skills, teamwork, ethical awareness, and an innovative mindset are equally essential for advancing medical technologies.

This paper is developed from the emerging interdisciplinary research areas under major institutional projects. It aims to explore innovative models for professional degree education in chemical engineering under interdisciplinary and societal demands. By thoroughly reviewing the current state of professional degree education in China and referencing to interdisciplinary integration from domestic and international universities, this study proposes a training model for high-quality interdisciplinary professionals in the context of medical-engineering integration.

The College of Chemical Engineering at Sichuan University serves as a vital foundation for high chemical engineering education and talent training in western China. The college recruits and trains professional master and doctoral students in areas such as materials and chemical engineering, resources and the environment, energy and power, and biomedicine. From the perspectives of universities, faculty, enterprises, and students, this study establishes a triadic "enterprise-laboratory-classroom" platform for integrating industry, teaching, and research. It proposes a "multidimensional, cross-temporal and spatial" training framework aimed at providing constructive recommendations for cultivating high-quality interdisciplinary professionals to meet national and industrial demands.

2. Main text

2.1 Integration of Industry, Teaching, and Research to Train Innovation Capabilities in Medical-Engineering Interdisciplinary Graduate Students

The integration of industry, teaching, and research is a critical strategy in professional degree education, designed to enhance the practical skills and professional qualities. This integration encompasses the merging of teaching and research, industry and education, and theory and practice. By combining scientific research with teaching, students actively participate in research projects, fostering research capabilities and innovative thinking. Strengthening collaborations between academia and industry promotes the sharing of resources and complementary advantages, enabling students to address real-world challenges and gain hands-on experience. Integrating theoretical knowledge with practical applications allows students to solidify the understanding through practice, thereby improving the overall quality of talent train.

The integration of industry, teaching, and research is vital for professional degree education, enabling students to adapt to professional demands, enhance overall competencies, and establish a solid foundation for future career development. For example, many universities establish industry-academy partnerships and training bases through collaboration agreements with enterprises. These partnerships facilitate joint research projects, technology transfer, and talent development. Enterprises provide funding support and technical guidance, and universities offer research outputs and a steady supply of skilled professionals. This collaboration allows enterprises to access cutting-edge scientific findings and talent resources, and universities align theoretical knowledge with practical needs, thereby improving both research quality and the effectiveness of talent cultivation.

Interdisciplinary integration in education fosters the simultaneous development of medical and chemical engineering fields, enabling students to achieve comprehensive growth. Under the context of "new engineering disciplines," chemical engineering advances in areas such as new energy, novel materials, and innovative technologies. These developments combine with medical disciplines can support healthcare initiatives, offering significant opportunities for reform and innovation in both disciplinary development and talent cultivation. By establishing resonance between teaching and research in both fields, knowledge, techniques, concepts, and methodologies are deeply integrated to achieve comprehensive interdisciplinary synergy.

2.1.1 Building multidisciplinary collaborative innovation platforms to broaden knowledge

Practical experience has demonstrated that multidisciplinary research platforms play a vital role in inspiring original thinking of postgraduate students, expanding professional knowledge, and cultivating engineering practice abilities. To achieve this, academic institutions should organize structures and establish well-regulated interdisciplinary development systems with clear trajectories for growth.

The course design for full-time professional master students should emphasize practical applications, closely aligned with industry needs, to cultivate comprehensive skills and practical abilities. The curriculum includes compulsory courses, degree courses, selective courses, and mandatory practical components. Collaboration with leading enterprises ensures that the course content is both relevant and leading. For example, in chemical reactor design courses, students work with prominent chemical companies to tackle real-world challenges, participating in production line optimization. Additionally, seminars on advancements in chemical and chemical engineering, featuring senior experts from organizations like Sinopec Research Institute, offer students lectures on the latest industry developments, enhancing their theoretical and applied knowledge. Sichuan University, in line with the national postgraduate education reform initiatives, has implemented a reform program for engineering master students training since 2023. The reform emphasizes the construction of practice-based curricula to enhance the quality of practical teaching, which has yielded promising results.

Under the framework of interdisciplinary collaboration between medicine and engineering, Sichuan University has developed a "science-engineering-medicine" research platform that integrates biomedicine with fields such as chemistry, physics, materials science, and electronics. This platform has become a critical resource for postgraduate education, enabling students to deepen their expertise while broadening their understanding of interdisciplinary needs. For instance, the college is currently developing a dual-degree program in "chemical engineering + medical examination." The comprehensive course structure and research exchanges facilitate the extension of interdisciplinary knowledge. In medical examination, aspects such as timeliness, accuracy, and convenience involve the design of high-performance devices and chemical processes (e.g., mass and heat transfer), offering students novel perspectives to apply their foundational knowledge in chemical engineering.

The development of interdisciplinary supervisory teams is central to student training on such platforms. Faculty members are encouraged to participate in interdisciplinary training and receive institutional support to expand curricula, adopt innovative models, and dismantle knowledge barriers between disciplines. Improvements to organizational management systems, teacher evaluation and promotion, and key training processes further ensure the high-quality development of interdisciplinary postgraduate education. Currently, all professional degree postgraduate students are paired with industrial supervisors, bridging academic knowledge and technical applications to meet industry demands, that boasts a 100% employment among graduates.

A project-based approach drives interdisciplinary postgraduate education, engaging students in research projects to acquire interdisciplinary skills. Comprehensive and reasonable cross-disciplinary evaluation systems and learning outcome assessments are integrated into teaching and research activities. This approach establishes a complete temporal sequence and spatial distribution of learning, encompassing diverse environments such as classrooms, research facilities, factories, and enterprises. Regular assessments ensure students master interdisciplinary knowledge and technologies effectively.

2.1.2 Strengthening foundational knowledge to achieve science – engineering - medicine integration

To align with the training requirements of "new engineering disciplines," changes should be made to the traditional professional master training model. A "multidimensional, cross-temporal and spatial" industry-teaching-research integration model shifts the focus from instructor-led teaching to stimulating initiative of students, ultimately improving talent cultivation quality. Integrating teaching and research is a critical theme in modern education, aiming to combine scientific research with teaching to enhance students' practical, innovative, and comprehensive skills. This integration allows students to apply their knowledge to their research, ensuring that learning is relevant and useful. This study, based on the experience of recent interdisciplinary projects in chemical materials and medical dentistry, proposes a multidimensional, cross-temporal and spatial industry-teaching-research integration model, which includes the following aspects:

2.1.2.1 Establishing an interdisciplinary professional master training model

An interactive approach combining online discussions and offline practice is adopted. A highly specialized, smart database is developed, featuring interdisciplinary technical solutions, key concepts, and case studies. This database minimizes obstacles students face when acquiring interdisciplinary knowledge. Under this model, students are encouraged to pursue their interests, actively engage in learning, and quickly master diverse knowledge and technologies across disciplines.

2.1.2.2 Building a shared knowledge database

Training in the medical-engineering interdisciplinary field requires integrating medical and engineering knowledge to meet evolving healthcare and technology needs. A shared database is established, including foundational general education content, cutting-edge research findings, group discussion data, and technical video demonstrations. This resource enables students to quickly review and acquire knowledge from various fields. New students can rapidly familiarize themselves with relevant concepts and techniques, accelerating their academic and research progress.

2.1.2.3 Developing an interactive teaching and research model

In this model, faculty integrate research findings into teaching to enhance the timeliness and relevance of guidance. Teaching and research complement each other, fostering a virtuous cycle. Faculty members incorporate cutting-edge academic knowledge—such as new chemical engineering technologies, foundational research outcomes, and applications of chemical engineering in biomedicine—into classroom teaching. This knowledge serves as the foundation for interest-driven research projects, whose outcomes feed back into teaching. Joint training programs with industry validate theoretical knowledge through practice, enabling students to transition seamlessly from classroom and laboratory learning to real-world applications.

2.1.2.4 Comprehensive curriculum development

Integrating theory and practice is the core of application-oriented education reform. Schools are encouraged to enhance discipline-specific training, update course content, and offer interdisciplinary seminars. Innovative teaching methods combine theoretical knowledge from various fields with practical applications through foundational experiments, professional laboratory work, and advanced equipment use. Internships further integrate industry and education, while independent projects in frontier fields bridge science and teaching. These approaches deepen students' understanding of biomedical production and research directions while fostering new engineering competencies. Courses such as "imaging technology," "spectroscopy," and "chromatographic separation techniques" are designed to serve both medical and chemical engineering students, broadening their horizons. Digital teaching tools facilitate interactive learning through steps such as "assigning tasks," "activating prior knowledge," "introducing new concepts," "online evaluations," and "demonstrating outcomes."

2.1.2.5 Integrating ideological and political education into courses

Rooted in the principle of moral education, this approach integrates values education, knowledge dissemination, and skill development. Thoughtful exploration of ideological and political elements within professional courses ensures alignment with social values and responsibilities. For example, mission of chemical engineering is to building on foundations, advancing industries, and serving society, is highlighted alongside core societal values such as legal awareness, cultural confidence, and scientific integrity. This model fosters patriotism, societal responsibility, and innovative thinking, cultivating students with comprehensive personal and professional competencies.

2.2 Expanding Training through Medical-Clinical Problem-Solving

The innovative training models explored above aim to cultivate interdisciplinary technical talents who can quickly integrate into and serve society, that should meet the following standards.

2.2.1 Mastery of fundamental theories and professional knowledge in medicine and engineering

Graduates should possess a solid foundation in the fundamental theories and specialized knowledge of medicine and engineering. They must be capable of applying this knowledge to solve real-world issues in the fields of medicine and healthcare.

2.2.2 Competence in disease-oriented interdisciplinary medical research

Graduates should be equipped to conduct research targeting disease-oriented challenges. This includes studies on key technologies such as medical devices, imaging techniques, and treatment methods. For example, addressing the quenching of fluorescent molecules during live-dead cell staining requires the development of new fluorescent molecules and the optimization of detection environments.

2.2.3 Problem-Solving skills for field-specific challenges

Graduates must possess the ability to address practical issues within their disciplines, including designing and improving medical equipment, developing new diagnostic methods, and optimizing therapeutic strategies. For instance, in the application of high-temperature erbium lasers, research into the thermal conduction mechanisms and methods for improving performance is critical.

2.2.4 Professional ethics and innovative spirit

Graduates should demonstrate strong communication skills, teamwork abilities, and ethical awareness. They must possess an innovative mindset to drive continuous progress in medical technology.

3. Conclusion

To respond to the national call for cultivating high-level interdisciplinary talents and to promote the deep integration of research and teaching, it is essential to construct a sustainable talent development chain for high-quality professionals. This project proposes a "multidimensional, cross-temporal and spatial" industry-teaching-research integration model for student training. By fostering deeper exchanges among students, faculty, and enterprises, the model establishes a novel network for cultivating high-caliber interdisciplinary professionals in universities. This approach addresses the shortage of skilled interdisciplinary talents in China and proposes innovative pathways for training *new* *engineering discipline* professionals.

The proposed model explores the essence of interdisciplinary professional master's training, offering a theoretical foundation that can serve as a reference for similar educational reforms in other institutions. It also promotes innovative models for training within the chemical engineering plus other fields framework, creating a favorable developmental landscape for professional master programs. Through integrating teaching and research, establishing shared knowledge repositories, and fostering enterprise collaboration, this model enhances the capabilities of professional master students and align their training with social demands. Such a development paradigm has significant potential for broader application and promotion.

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