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Research and Practice on the "One Core, Two Wings" Innovation Talent Cultivation Model for Mechanical Engineering in the Context of New Engineering Education

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Abstract: ***Facing the challenges brought by the new round of technological revolution and industrial transformation under the context of New Engineering Education, this paper proposes an innovation talent cultivation model for mechanical engineering called "One Core, Two Wings." This model aims to comprehensively enhance students' overall quality and innovation ability by constructing a curriculum system that integrates both general and specialized knowledge with a spiral development approach ("One Core"), along with a hybrid teaching organization and a practice-driven teaching model ("Two Wings"). The paper elaborates on methods for course reconstruction, including building a networked bridge connecting multi-disciplinary knowledge fragments, optimizing the integration of general engineering courses, and incorporating frontier knowledge from mechanical engineering into the specialized education curriculum. It also introduces a hybrid teaching and research organizational structure, as well as a practice-driven teaching mode, where real-world engineering problems, cases, projects, and research outcomes from industry are brought into classroom teaching through a collaborative model of industry-university cooperation. Through these innovative measures, this paper aims to provide a systematic solution for the cultivation of mechanical engineering talents, as well as for the wider New Engineering Education talent training, to foster interdisciplinary and innovative talents capable of leading technological innovation and solving complex engineering problems.***

Keywords: New Engineering Education, Innovation Talent Cultivation Model, Mechanical Engineering, Interdisciplinary Integration, Spiral Curriculum System.

1. Introduction

With the continuous deepening of New Engineering Education, new requirements have been proposed to "actively respond to the challenges brought by the new round of technological revolution and industrial transformation," both for "emerging engineering disciplines" and for the "optimization and upgrading of traditional engineering disciplines." For the mechanical engineering industry, the challenge brought by the "new round of technological revolution and industrial transformation" lies in how to transition from traditional "mechanical automation" that replaces manual labor to "mechanical digitalization" that replaces both manual and intellectual labor, aimed at the future. This challenge calls for a shift in mechanical engineering talent cultivation from traditional "pure mechanical" application ability training to a new model of cross-disciplinary, innovation-driven talent development that integrates "mechanical + computer science," "mechanical + electrical control," "mechanical + artificial intelligence," "mechanical + information," and "mechanical + X."

With the advent of the new technological revolution and industrial transformation, traditional mechanical engineering education faces unprecedented challenges. To better serve national strategies, meet industrial needs, and prepare for future development, higher education institutions must explore new educational models to cultivate interdisciplinary and innovative talents capable of leading technological innovation and solving complex engineering problems. Against this backdrop, this paper proposes an innovation talent cultivation model for mechanical engineering, named "One Core, Two Wings." This model aims to break down the disciplinary barriers that exist in traditional education by constructing an integrated, spiral curriculum system ("One Core"), along with a hybrid teaching organization and practice-driven teaching model ("Two Wings"), to comprehensively enhance students' overall quality and innovation capabilities. This paper will provide a detailed introduction to the design thinking, implementation path, and application case of this model at the School of Mechanical Engineering at Harbin Engineering University, hoping to provide useful references and insights for mechanical engineering talent cultivation in China and, more broadly, for New Engineering Education.

2. "One Core, Two Wings" Cultivation Model

From the perspective of serving national strategies, meeting industrial needs, and preparing for future development, this model aims to construct a talent cultivation system for mechanical engineering that focuses on capabilities and reflects the school's educational positioning and characteristics. The model addresses the interrelationships between knowledge points, ability points, innovation points, thinking training points, and engineering practice points in the context of New Engineering Education. It follows the approach of multidisciplinary integration, industry-academia-research collaborative education, and deep engineering learning. The curriculum system and project-based teaching design are systematically constructed to foster an interdisciplinary, collaborative, and innovative talent cultivation model throughout the undergraduate process, both inside and outside the classroom.

Focusing on the challenges brought to the mechanical industry by the new technological revolution and industrial transformation, and aiming at the needs of interdisciplinary and innovation-driven talent development in the context of smart manufacturing, this model breaks down boundaries between schools, disciplines, knowledge, learning, and classrooms. It addresses three aspects in New Engineering Education: the "new structure" of professional and disciplinary systems, the "new methods" of teaching and learning organization, and the "new pathways" for practice-based teaching. The model introduces international advanced educational concepts and management modes, draws on, merges, and innovates continuously, conducting in-depth systematic research. The "One Core, Two Wings" interdisciplinary, innovation-driven talent cultivation model is constructed with an integrated, spiral curriculum system at the core, hybrid teaching organization forms, and practice-driven teaching models as the "wings." The goal is to cultivate students' overall quality, problem-solving abilities for complex engineering issues, innovation and entrepreneurship skills, adaptability, and social skills in team-based settings.

Through a case study at the School of Mechanical Engineering at Harbin Engineering University, this paper discusses methods for reshaping fragmented knowledge into a cohesive curriculum system and reconstructing teaching content, approaches for linking interdisciplinary knowledge points in project-based teaching design, and the construction of a "hybrid" teaching and research organizational structure that integrates both vertical depth and horizontal breadth. These methods provide valuable references for cultivating top-notch innovative talents in mechanical engineering, and by extension, offer insights for building talent cultivation systems in other engineering disciplines under the framework of New Engineering Education.

2.1 One Core: Course Reconstruction

This section proposes a cross-disciplinary course reconstruction method that aligns with cognitive principles, building a networked bridge to connect multi-disciplinary knowledge fragments. The aim is to address the issue where traditional, discipline-segmented course content makes it difficult for students to understand the interdisciplinary coupling relationships between different fields, thus hindering their ability to integrate and apply multi-disciplinary knowledge. The entire curriculum system is constructed based on the logical framework of mechanical engineering, strengthening fundamental mathematical and physical courses, encouraging cutting-edge cross-disciplinary courses, and guiding industry-academia integrated practical courses. The main research content includes:

Integrating and reorganizing engineering technology foundation courses to support the development of multidisciplinary integrated professional education;

Developing new professional courses that integrate multiple disciplines, fostering students’ interdisciplinary thinking and cross-field integration abilities;

Incorporating frontier knowledge from mechanical engineering, along with interdisciplinary knowledge, principles, and methods from fields such as intelligent manufacturing, artificial intelligence, and information technologies, into the professional education curriculum system to broaden students’ perspectives and cultivate their future capabilities.

2.2 Two Wings: Hybrid Teaching and Research Organization + Practice-driven Teaching Model

The virtual teaching and research office is a new type of grassroots teaching organization that uses information-based, intelligent teaching methods to conduct hybrid teaching research activities both online and offline in the "Intelligent +" era. This project will establish a "hybrid" teaching and research organizational model, exploring a matrix-style teaching research organization that groups courses horizontally and disciplines vertically, combining both virtual and physical components. This structure will provide teaching team support for the development of cross-disciplinary courses, aiming to resolve the contradiction between traditional grassroots teaching organizations divided by research direction and the urgent need for teaching teams capable of fostering interdisciplinary integration.

"Practice-driven" will create a three-in-one collaborative innovation model combining science-education integration, industry-academia cooperation, and school-enterprise collaboration. This model will focus on project-based teaching to link fragmented interdisciplinary knowledge points, bringing real-world engineering problems, cases, projects, and research outcomes from industries into the classroom and textbooks. This will achieve a complementary "learning by doing, doing by learning" effect. The model also aims to deepen the integration of industry and education both inside and outside the classroom, constructing cognitive, professional, comprehensive, and research practice platforms. Students will be given stage-based, tiered, and categorized practice training. The internal and external collaboration in innovation is designed to address the limitations of traditional teaching models, which fail to meet industry needs and do not effectively prepare students to tackle future technological challenges in the engineering sector.

3. New Engineering Education Strategy for Cultivating Interdisciplinary, Innovation-driven Talents in Mechanical Engineering

In the context of New Engineering Education, traditional curriculum systems, grassroots teaching research organization models, and teaching methods in mechanical engineering education have revealed a disconnect with the goals of talent cultivation in the new era. Specifically, the traditional curriculum system, based on fragmented academic specialization, cannot support the integrated application of "mechanical +" multidisciplinary knowledge and the cultivation of interdisciplinary talents, which limits students' ability to solve complex engineering problems. Additionally, traditional grassroots teaching research organizations are typically based on research directions, which contradicts the urgent need for teaching teams capable of fostering interdisciplinary integration, thus hindering the effective integration and collaboration of teaching resources. Moreover, the traditional teaching model has become rigid in the face of rapid societal changes and fails to adapt to the cultivation of innovative thinking and dynamic adaptability needed for the technological revolution in the future. As a result, students are ill-prepared to face emerging technological challenges and industry transformations.

In light of these issues, this study aims to systematically resolve these contradictions by constructing the "One Core, Two Wings" talent cultivation model for mechanical engineering. The core of this model is an integrated, spiral curriculum system that blends general and specialized knowledge, while the "wings" are represented by hybrid teaching organization structures and practice-driven teaching models. The specific implementation plan includes:

First, optimizing the curriculum system based on the "One Core, Two Wings" concept through multi-level, multi-channel research to clarify the talent cultivation goal and to map the knowledge structure of mechanical engineering, building a systematic interdisciplinary curriculum.

Second, innovating hybrid teaching research organization forms by constructing matrix-style research teams to promote the integration and sharing of interdisciplinary knowledge.

Third, designing interdisciplinary project-based teaching that integrates real-world engineering problems from industry into the curriculum, achieving deep integration of "learning by doing, doing by learning."

Finally, establishing an industry-education integrated practice-driven cultivation mechanism, providing students with stage-based, tiered, and categorized practical training platforms to strengthen their engineering practice and innovation abilities.

These measures will effectively advance mechanical engineering education to higher levels, cultivating outstanding innovation-driven talents capable of addressing future technological revolutions and industrial transformations.

3.1 Research Approach and Methods

The research begins by conducting a study and forecast of future talent demands in the mechanical engineering industry, adjusting talent cultivation goals and standards, and researching the informatization, intelligence, and integration of the existing mechanical engineering discipline. Subsequently, the cultivation plan will be formulated, focusing on the construction of the curriculum system, hybrid teaching organization, and practice-driven teaching model. The goal is to build the "One Core, Two Wings" innovation talent cultivation model.

3.2 Course System Reconstruction

The New Engineering Education curriculum system is divided into four levels:

General foundation courses
Professional foundational courses
Professional core courses
Professional extension courses

For the general foundation courses, including mathematics and humanities, the focus is on integrating the overall curriculum setting of the institution. Here, the main research is on constructing the engineering technology foundation general education courses.

With the aim of fully implementing the professional cultivation goals and standards, this project adopts a "top-down" approach to systematically map the knowledge structure of mechanical engineering, analyzing the interrelationships between knowledge points, ability points, innovation points, thinking training points, and engineering practice points. The knowledge and course modules are then organized according to cognitive principles to create logical connections between them.

In the early stages, the courses on *Design Methodology*, *Engineering Drawing*, *Mechanical Design*, *Mechanical Principles*, *Mechanical Precision*, *Control Engineering*, *Mechanical Manufacturing Technology*, and *Intelligent Manufacturing Technology* are integrated, and course boundaries are redefined. A three-tier, five-module curriculum system titled *Engineering Systems Design I-V* is constructed, as shown in Figure 3. Using *Engineering Systems Design I-V* as the main framework, core professional courses, cutting-edge development courses, professional training series, and specialized courses are designed, with teaching cases linking the knowledge modules. The curriculum progresses from lower to higher grades in a spiral manner, dispersing complex content to ensure that advanced knowledge is fully absorbed. This approach forms a systematic mechanical engineering curriculum system in New Engineering Education, which meets the talent cultivation goals necessary for adapting to future industrial developments.

3.3 Hybrid Teaching and Research Organizational Structure

To ensure the continuity and progression of cross-disciplinary course groups, research on the hybrid teaching and research organization model is conducted. The model relies on internal academic organizations within the college: the Department of Mechanical Design and Automation, the Department of Mechatronics, the Department of Intelligent Manufacturing Engineering, the Engineering Drawing Research Center, and the Mechanical Fundamentals Research Center. These departments collaborate both vertically and horizontally to complete the construction of cross-disciplinary courses and interdisciplinary project-based teaching designs.

The academic organizations within the departments play a guiding role in the curriculum reform, leading teachers in course construction. Based on the need for cross-disciplinary courses, multi-disciplinary teachers are recruited to collaborate horizontally, ensuring continuity across knowledge modules. Physical support, virtual connectivity, and hybrid teaching structures break down disciplinary barriers. By combining virtual and physical teaching research organizations, the model breaks down barriers between disciplines and departments, achieving a systematic approach to talent cultivation. The construction of this hybrid teaching and research organizational structure is illustrated in Figure 4.

3.4 Practice-driven Teaching Model

Practice is the essence of engineering and the foundation of innovation. In the practice-driven teaching model, projects are designed to complement each other inside and outside the classroom, creating projects directly aligned with industrial needs. These projects apply to various levels of practice activities, including engineering cognition, professional engineering practice, comprehensive project practice, research innovation practice, and graduation design, forming a project-based teaching system that cultivates students' ability to translate course knowledge into practical problem-solving skills. The project-based teaching model first requires coordination with industry to develop the project content, which is then integrated with the practice activities, ultimately providing the most efficient platform for student practice. To achieve this, efforts must focus on the following three areas:

External Practice Resource Construction: Strengthening cooperation with enterprises and research institutions to build various types of external internship and practice bases. Real-world cases and problems from industries and research institutions are introduced into the classroom, with teaching projects based on these industry cases and issues.

Resource Integration: Aligning existing basic practice education resources with New Engineering Education project-based teaching needs, integrating them into a comprehensive resource system. Teaching projects are then embedded into various stages of engineering cognition, professional practice, research innovation, and graduation design.

Upgrade and Transformation: Integrating existing practice education resources with other related disciplines’ practice resources to transform them into digitalized, intelligent, and comprehensive laboratories. The latest teaching equipment is used to provide virtual simulation teaching projects, offering students a project practice platform at the lowest cost and highest efficiency.

This paper aims to construct an innovation talent cultivation model for mechanical engineering that adapts to the context of New Engineering Education. The "One Core, Two Wings" model has a core curriculum system that integrates general and specialized knowledge, enhancing cross-disciplinary capabilities. The hybrid teaching research organization and practice-driven teaching model serve as the "wings," offering students in-depth engineering education and industry practice platforms. These innovations effectively address the issues of subject fragmentation and lack of cross-disciplinary collaboration in traditional education models, driving mechanical engineering education to higher levels and cultivating outstanding engineering talents who are prepared to meet the challenges of future technological revolutions and industrial transformations.

4. Conclusion

This paper proposes an "One Core, Two Wings" innovation talent cultivation model for mechanical engineering in the context of New Engineering Education. The aim is to cultivate interdisciplinary, innovation-driven talents who can respond to the challenges of future technological revolutions and industrial transformations. The core of this model lies in constructing an integrated, spiral curriculum system that blends general and specialized knowledge, supplemented by a hybrid teaching organization and practice-driven teaching model.

4.1 Course Reconstruction:

The course reconstruction section presents a cross-disciplinary curriculum reconstruction method that aligns with cognitive principles, aiming to build a networked bridge that connects multidisciplinary knowledge fragments. By integrating and optimizing engineering technology foundation courses, developing new interdisciplinary professional courses, and incorporating frontier knowledge from mechanical engineering and related interdisciplinary fields into the professional education curriculum, this research addresses the problem in traditional curricula where knowledge is segmented by discipline, making it difficult for students to understand and apply the interrelationships between different fields. This reconstruction method not only strengthens the foundation courses in mathematics and physics but also encourages the development of interdisciplinary courses and guides the integration of industry-academia practical courses, enhancing students' interdisciplinary thinking and cross-disciplinary integration abilities.

4.2 Hybrid Teaching and Research Organizational Structure:

The hybrid teaching and research organization section constructs a matrix-style teaching research organization model that groups courses horizontally and disciplines vertically, combining both virtual and physical elements. This model uses virtual teaching research offices as a new grassroots teaching organization in the "Intelligent +" era, combined with traditional physical teaching research offices, breaking the limitations of the traditional organization structure that divides research based on directions. It ensures the effective collaboration of multidisciplinary teaching teams required for the development of cross-disciplinary courses.

4.3 Practice-driven Teaching Model:

The practice-driven teaching model section constructs a collaborative innovation model that integrates science-education, industry-academia cooperation, and school-enterprise collaboration. This model brings real-world engineering problems, cases, projects, and research outcomes from industries into classroom teaching, achieving a deep integration of "learning by doing, doing by learning." Furthermore, by building cognitive, professional, comprehensive, and research practice platforms, students are provided with stage-based, tiered, and categorized practice opportunities to enhance their engineering practice and innovation capabilities.

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