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A Research Paradigm-integrated New-Quality Engineering Education Mode Driven by Industry-Education Integration

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Abstract: ***Against the strategic backdrop of developing new-quality productive forces and new industrialization, this study proposes an engineering education model based on reconstructing the teaching process through research paradigms to resolve the threefold disconnect among knowledge, capabilities, and resources. The teaching process is divided into classroom instruction and project-based design, with seminar-based learning conducted in class and research-oriented project design carried out outside class. Furthermore, it clarifies the roles of teachers and students throughout the teaching process, positioning students as the main participants and teachers as guides. Through systematic practice, this model enhances students' ability to independently innovate when addressing complex engineering challenges, providing a model for engineering education reform in the new era that can be adapted and applied in other contexts.***

Keywords: New quality productive force, Cultivation mode, Teaching process reconstruction, Ideological and political integration, Industry-education integration**.**

1. Introduction

As traditional knowledge-transmission models become increasingly inadequate, global engineering education has entered a critical period of paradigm reconstruction [1-2]. Developed countries in Europe and North America place considerable emphasis on industry–education integration and research-oriented teaching within their engineering curricula. Specifically, the conceive-design-implement-operate (CDIO) engineering education framework pioneered by MIT underscores learning driven by "engineering systems thinking + industrial cases," highlighting systematic training in interdisciplinary projects and innovative methodologies [3]. Other nations, such as the UK and Germany, have incorporated industrial R&D challenges into instructional scenarios, utilizing dual education systems to establish an integrated pathway spanning "research questions–curricular modules–practical deliverables" [4-5]. Although China's Emerging Engineering Education initiatives have vigorously advanced industry–education integrated curriculum systems, they focus mainly on incorporating practical components into the curriculum, leaving the deep integration between course content and authentic, complex industrial systems largely insufficient [6]. The development of talent suited to the needs of new-quality productive forces continues to face three structural challenges [7-8]: curricular updates lag behind industrial progress, leading to fragmented knowledge structures; practical training overemphasizes confirmatory experiments and lacks systematic exposure to complex engineering scenarios, resulting in inadequate practical problem-solving capabilities; and university-enterprise collaboration remains loosely coupled, with slow resource updates and limited functionality. Consequently, to cultivate innovative mechanical engineering talent adapted to new-quality productive forces, there is an urgent need to explore an educational reform pathway based on reconstructing the teaching process through research paradigms, thereby establishing a new-quality engineering education model that can be adapted and applied in other contexts [9].

Addressing the strategic demands for digital innovation in the modern engineering equipment manufacturing industry, curriculum digital transformation serves as a pivotal leverage point to drive the multi-tiered synergistic linkage across the "specialty-curriculum-classroom" system, thereby advancing the iterative evolution of the new-quality innovative talent cultivation paradigm. As a core course within the coherent theory-practice integrated cultivation framework for mechanical engineering majors, Mechanical System Dynamics encompasses intersecting interdisciplinary domains, including dynamic design, the finite element method, data-driven techniques, and model-based systems engineering (MBSE) methodology, aimed at bolstering students' digital innovation capacities in high-end equipment R&D. Therefore, taking the embodied cognition instructional design of Mechanical System Dynamics as an example, this study constructs a new-quality teaching model based on reconstructing the teaching process through research paradigms, fostering students' proactive innovation awareness, engineering systems thinking, and innovative practical capabilities.

2. A New-Quality Engineering Education Cultivation Mode

2.1 Construction of a "Personalized and Modular" Curricular Content System

Targeting emerging strategic sectors under China's "maritime power" strategy and international frontier developments, this curriculum focuses on the design and development of gear transmission devices, covering key technologies for predicting and controlling vibration and noise in gear

transmission systems. By systematically incorporating industry-university-research achievements and authentic corporate engineering cases into instructional practice, a seamless alignment is realized between curricular content and engineering practice, between the pedagogical process and the R&D trajectory, and between fundamental scientific research and industrial deployment. Centered on the structural knowledge demands of engineering challenges, reform approaches are systematically explored in relation to course objectives, content, teaching models, methods, resources, and tools, reshaping the curricular knowledge framework, pedagogical methodologies, and talent cultivation patterns. This deepens graduate students' understanding of engineering equipment R&D processes and achieves an organic alignment between corporate talent demands and graduate training goals.

Taking the integrated load-bearing and vibration-damping design of engineering equipment as an entry point, the curriculum knowledge structure is reconstructed from both component-level and system-level perspectives to form a hierarchical list of knowledge points and competencies. Modular curricular units are developed to redefine course boundaries, distill small-scale research training projects, and plan high-quality textbooks on research methods and frontier developments. Grounded in the conceptual process model of engineering equipment innovative design, personalized learning tasks are formulated to investigate a project-based pedagogical mapping mechanism synchronizing the product development chain with the instructional timeline. Furthermore, a comprehensive evaluation system covering the entire teaching process and all relevant elements is established to encourage student technological innovation. Through the collaborative development of virtual simulation experiments integrated with small-scale research training projects, students are guided toward "learning by doing" and "learning through practice".

2.2 Constructing a Virtual-Physical Integrated Ubiquitous Learning Environment

In close alignment with corporate management, design, development, and manufacturing workflows, this approach develops instructional micro-lecture video resources, master lecture series, engineering case repositories, and learning feedback systems. These diversified resources are systematically orchestrated around university-enterprise collaborative projects, fully embodying the practical orientation and engineering relevance of instructional content and tasks.

A virtual platform for classroom teaching through university-enterprise collaboration is developed to institutionalize the regular development, implementation, evaluation, feedback, and updating of teaching resources. By integrating an online teaching service platform, a virtual simulation teaching platform, a mobile learning micro-platform, and a service platform management system, a knowledge base for online teaching services is established, promoting real-time interaction between the teaching process and industrial R&D activities.

By mapping real classrooms into cloud-based virtual spaces and incorporating operational data, behavioral rules, and personalized learning guidance into virtual models and student digital twins, a realistic cloud-based classroom environment is developed. Leveraging the ThingJS-X digital twin platform by UINO, functional modules-including virtual classrooms, digital twin models, data analysis and visualization, personalized learning management, and real-time interactive tools-are developed to create a more dynamic and sustainable cloud-based teaching model.

2.3 Coherent Cultivation Integrating Ideological-Political Education and Innovation

The teaching team cultivates faculty members who are skilled at identifying scientific and engineering problems and telling stories about revolutionary history, seamlessly integrating real-world engineering challenges and practical solutions into ideological and political education. By studying the theories and teaching methods of curriculum-based ideological and political education, the team strives to build a high-quality, professional, and innovative teaching staff. Leveraging scientific research to invigorate teaching, instructors profoundly mine ideological and political elements embedded within the innovative design of modern complex electromechanical products, meticulously devise instructional schemes, and continuously enhance their capacity for ideological and value guidance. By examining the development history of national defense equipment and exploring the ideological elements embedded in core disciplinary knowledge, engineering applications, and frontier developments in modern design methods, the achievements of defense modernization are highlighted to present Chinese narratives, cultural elements, and values, reflecting national priorities and social responsibility. Furthermore, an integrated repository of engineering cases and ideological elements is developed to build high-quality online resources, reflecting the view that innovation is a key driver of development with Chinese characteristics, together with a people-centered approach.

Relying on curricular resources distinguished by marine and naval architecture disciplines, a bidirectional mapping between national defense scientific research achievements and the theoretical tenets of modern design methods is established. Driven by innovation leadership, this approach reshapes the knowledge architecture of modern electromechanical product analysis and design. Moral education elements are emphasized through modular curriculum restructuring, interdisciplinary extension, and the inclusion of frontier research, stimulating students' intrinsic motivation to innovate and fostering an innovative spirit that is gradually internalized into engineering literacy embodying the unity of knowledge and action. By feeding national defense scientific research outcomes back into instructional practice, authentic product R&D contexts are formulated from the perspective of cultivating autonomous innovative design capacities for modern machinery. This facilitates the deep integration of practical work education with professional coursework and innovation-entrepreneurship activities, promoting coordination between formal classroom instruction and extracurricular learning (the "first and second classrooms"). Concurrently, industrial design aesthetics and aesthetic education are deeply infused into the R&D trajectory of engineering equipment, realizing an organic symbiosis

between disciplinary academic value and holistic educational value. Moreover, personalized developmental dossiers tracking students' ideological evolution are established to construct a diversified, collaborative instructional assessment system, leveraging big data analytics to trace and evaluate the pedagogical efficacy of ideological and political education in fostering students' engineering literacy.

3. Implementation and Outcomes of the Talent Cultivation Mode

3.1 Integration of Engineering Literacy Development and Knowledge Instruction

Driven by the innovative design of gear transmission devices, the curriculum systematically identifies common technologies and methods in marine engineering equipment design, reconstrucules on modern design methods, and integrates industry–university collaboration outcomes to develop small-scale research training projects. Grounded in Bloom's taxonomy of educational objectives and guided by the Outcome-Based Education (OBE) philosophy, it uses heuristic, inquiry-based, and project-driven teaching methods to develop students' engineering literacy, including engineering ethics, computational thinking, higher-order thinking, and collaborative innovation.

3.2 Unification of Autonomous Learning and Virtual-Physical Integration

A multi-tiered, modular online teaching platform has been developed, establishing a ubiquitous autonomous learning mode that combines in-class and out-of-class learning with virtual-physical integration. Through the coordinated development of an online teaching service knowledge base, an autonomous learning management system, and a virtual simulation platform, the curriculum meets graduate students' needs for convenient, customized, and personalized learning. Relying on this online teaching platform based on virtual-physical integration, graduate students are encouraged to transition from passive knowledge recipients into active, inquiry-driven practitioners.

4. Conclusion

Driven by research projects and disciplinary developments, this approach strengthens the supportive and leading role of university–enterprise collaboration outcomes in curriculum restructuring. By developing an engineering case repository and small-scale research training projects, teaching activities are integrated throughout the entire process of competency development, establishing an updated teaching model that connects research with instruction. Taking technological R&D as a breakthrough point, universities and enterprises have jointly built a comprehensive platform for talent development that integrates classroom teaching, research training, and technical services. This initiative promotes a cultivation environment characterized by the integration of disciplines and specialties, interaction between teaching and research, and mutual growth among peers. Furthermore, by developing high-quality research-oriented and frontier courses, the initiative promotes the online delivery of courses taught by distinguished professors and standardizes online instruction, effectively improving teaching quality and the effectiveness of education in fostering students' overall development.

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