Research and Practice on Multidisciplinary and Multilevel Interdisciplinary Integration for Practical Education Based on the China International College Students' Innovation Competition

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Abstract: This study investigates the practice of multidisciplinary and multi-level integration based on the China International College Student Innovation Competition (CICIC). It details the achievement of objectives regarding the project-based innovation practice model, the development of multidisciplinary teams, and the establishment of innovation practice bases. The paper introduces teaching reforms and their impact on cultivating innovative talents, analyzes the dissemination and application of project outcomes, summarizes the innovative characteristics of the practical education ecosystem, pathways, and paradigms, identifies existing challenges, and outlines the next phase of the promotion plan, thereby offering insights for practical education in higher education institutions.

Keywords: China International College Student Innovation Competition; Multidisciplinary; Practical Education; Industry-education Integration; Talent Cultivation

1. Introduction

Under the strategic backdrop of national innovation-driven development and the revitalization of science and education, the traditional single-discipline training model has become inadequate for addressing technological challenges and complex societal demands. Interdisciplinary integration has emerged as a core focus of higher education reform. The practice of Dongbei University of Finance and Economics has shown that financial disciplines need to break through the cultivation bottleneck through interdisciplinary integration to serve national strategies [1]. Similarly, Tianjin University's integrated talent cultivation model in integrated circuit engineering confirms that interdisciplinary collaboration and the integration of science, education, industry, and talent development significantly promote the cultivation of high-end professionals [2]. Concurrently, academic competitions serve as vital platforms for practical education, with their synergistic value in interdisciplinary integration becoming increasingly evident. For instance, disciplines like humanities and geography, driven by competitions and research projects, have developed talent cultivation pathways through curriculum integration and pedagogical reform [3]. Additionally, research on multidisciplinary integration mechanisms within the context of "Internet+" competitions indicates that resource sharing across disciplines and the construction of practical platforms are crucial for cultivating versatile, interdisciplinary professionals [4].

However, current research still faces dual limitations: firstly, the cultivation of top-tier talents at local universities encounters systemic barriers such as organizational restructuring and resource coordination when promoting interdisciplinary integration [5]. Similarly, innovation and entrepreneurship education for normal university students reveals issues like a monotonous project-based approach and insufficient innovation reserves [6], reflecting disparities in the implementation of interdisciplinary fusion at various levels. Secondly, although multidisciplinary practices have been conducted in fields such as robotics competitions [7] and BIM technology [8], there remains a lack of systematic exploration into the mechanisms for deeply integrating practical education within comprehensive events like the China International College Student Innovation Competition, which covers multiple disciplines and levels. While the "competition-driven teaching" philosophy aligns closely with the needs of interdisciplinary talent development [9], existing studies predominantly focus on single-discipline competitions (e.g., the International Aerial Robotics Competition [10], Hydraulic Mechanical Arm Contest [11]), and have yet to establish a collaborative framework for integrating multidisciplinary knowledge and cultivating multi-level competencies.

Based on this, this paper takes the China International College Student Innovation Competition as a starting point. By analyzing the intersection of the competition's characteristics and educational needs, it explores practical approaches and support systems for interdisciplinary integration. This aims to provide both theoretical and practical guidance for higher education institutions to leverage comprehensive competitions in fostering innovative talent development [12-14].

2. Progress Status of the Construction Objectives

2.1 Development of an Innovative Project-Based Practice Model

In the 2023-2024 academic year, we conducted freshman orientation through exhibitions of innovation and entrepreneurship achievements, as well as activities during the Innovation and Entrepreneurship Month, reaching over 3,200 participants and surpassing the annual target. We offered 14 practical courses related to innovation and entrepreneurship, including "Aircraft Control Technology," establishing a curriculum system of "Fundamental Cognition - Professional Deepening - Cross-disciplinary Integration," which has engaged a total of 2,543 students. Additionally, we integrated industry-education collaboration projects to facilitate 12 undergraduate graduation internships. Relying on university student innovation projects, disciplinary competitions, and corporate research initiatives, we undertook 42 industry-education integration projects, with two, such as the "Intelligent Safety Monitoring System," achieving industrial application, thereby supporting the intelligent transformation of the power industry. This model employs a progressive design of "Enlightenment - Curriculum - Projects" to break disciplinary barriers and build an innovative educational system that integrates theory and practice.

2.2 Interdisciplinary Collaboration in Student and Faculty Team Development

2.2.1 Interdisciplinary student innovation team development

Relying on innovative clubs such as "Robotics" and "Virtual Reality," we have conducted technology training and competition activities, engaging a total of 1,000 students. The "Specialized + Power Robotics" club enrolled 40 members and offered courses like "Fundamentals of Robot Control." Our developed projects, including the "Insulation Coating Robot," received the Gold Award at the 2023 National Competition, while the "Generator Air Gap Detection Robot" was awarded the Silver Medal at the 2024 National Competition.

2.2.2 Development of the "Dual-Teacher and Three-Guidance" instructional team

A mentorship team comprising 15 university faculty members and 63 industry experts was established to develop the "1+1+1" collaborative model (faculty + engineers + industry specialists). This team jointly supervises 42 industry-education integration projects, creating a training chain of "theoretical instruction - technical guidance - industry leadership," thus contributing to resolving interdisciplinary learning challenges and strengthening collaboration between universities and industry.

2.2.3 Development of an open innovation practice base

Establish innovation and entrepreneurship bases for intelligent manufacturing and robotics, operating with 24*7 open management. Develop an integrated platform encompassing design, processing, manufacturing, and testing to address challenges related to site, technology, and equipment support, providing comprehensive end-to-end support for innovation practices.

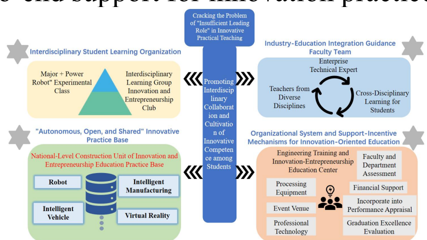

Figure 1. Interdisciplinary Cooperation and Innovation Ability Cultivation System

As shown in Figure 1, this is the diagram of the interdisciplinary collaboration and innovation capability development system. Through the coordinated efforts of student organizations, mentor teams, and practical platforms, a closed-loop educational model has been established, characterized by "interest-driven — technology-enabled — practice-implemented," thereby fostering the cultivation of interdisciplinary cross-disciplinary innovation skills.

2.3 Addressing Problems in Traditional Teaching Models

To address the limitations of the traditional linear instructional model of "teacher demonstration - student imitation - result evaluation" and the disconnect between innovation capability development and industry demands, a deep integration of competitions such as the China International Innovation Competition and the Mechanical Innovation Design Contest with curriculum development has been implemented. This approach constructs a four-tiered, multidimensional, and interdisciplinary course ecosystem comprising "Enlightenment Education - Fundamental Training - Competition-Led Development - Industry-Education Integration." As illustrated in Figure 2, this system integrates practical content from disciplines such as mechanical design, intelligent manufacturing, and automatic control, utilizing real engineering case studies. It encompasses students from multiple majors, including electrical engineering and automation, effectively overcoming the fragmentation of the curriculum system.

To address the drawbacks of the linear model in traditional practical teaching, which involves 'teacher demonstration-student imitation-result acceptance,' and the disconnection between innovation capability development and industry needs, a four-stage progressive, multi-dimensional interdisciplinary course ecosystem has been constructed through the deep integration of events and courses such as the China International Innovation Competition and the Mechanical Innovation Design Competition. This system, as illustrated in Figure 2, integrates practical content from multiple disciplines, including mechanical design, intelligent manufacturing, and automatic control, using real-world engineering case studies to teach students from various majors, such as power and automation, effectively addressing the issue of fragmented course systems.

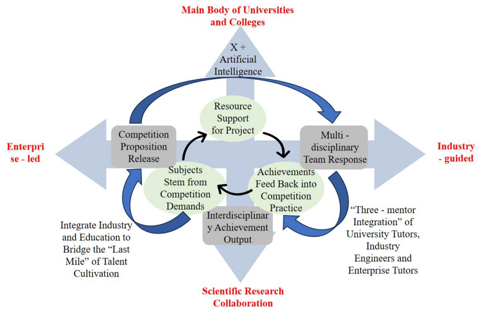

Figure 2. Diagram of the Training Mode of "Four-order Multi-dimensional" Engineering Innovation Talents

During the enlightenment education phase, we offer 13 Massive Open Online Courses (MOOCs) on freshman orientation and practical education. We establish an annual Innovation and Entrepreneurship Month, organize university-industry joint innovation and entrepreneurship lectures, base visits, showcase of outstanding achievements, and exchanges with distinguished entrepreneurial alumni. These initiatives aim to cultivate a mindset of innovation and entrepreneurship among new undergraduate students.

During the foundational training phase, I developed 14 compulsory and elective courses including "Fundamentals of Smart Grids," "Introduction to New Energy Technologies," and "Basics of Robot Control." I independently designed 18 types of experimental platforms to facilitate immersive teaching. Through 16 university student innovation and practical projects, I cultivated students' fundamental technical skills and fostered their innovative thinking.

During the competition-led phase, multidisciplinary student and faculty teams engage in eight categories of contests, including electronic design, intelligent vehicles, energy conservation and emission reduction, and robotics. A three-tier selection mechanism-comprising university, provincial, and national levels-is established, along with specialized training camps and dedicated competition funds. By participating in comprehensive contest projects that encompass component design, material procurement, fabrication, assembly, and debugging, students systematically enhance their design thinking and engineering practical skills, while also strengthening cost awareness and systemic thinking.

During the industry-education integration phase, aligned with the needs of the power sector, we transform frontline engineering innovation cases into a research project database for entrepreneurship and innovation. We develop modular practical courses for 42 industry-education integrated projects, such as "Substation Inspection Robot Research," "Transmission Line Ground Repair Robot Research," and "Power Plant Pipeline Clearing Robot Research." The course content is regularly updated in line with technological advancements in the industry, forming a dynamic, iterative curriculum system that ensures the technical comprehensiveness and cutting-edge nature of innovation projects, thereby enhancing students' innovation and entrepreneurial capabilities.

3. Project Research Practice

3.1 Practice of Teaching Reform

To address issues such as the fragmented scattershot approach and the lack of a progressive system in traditional practical teaching, a four-stage, multidimensional interdisciplinary curriculum framework has been proposed (as illustrated in Figure 3). This innovative structure pioneers a four-tiered practical model: "Enlightenment Education - Fundamental Training - Competition-Led Learning - Industry-Education Integration," integrating multidimensional practical content such as mechanical design and intelligent manufacturing. This approach facilitates a transition from a "knowledge-centered" to a "competency-centered" pedagogical pathway. Fourteen practical courses, including "Fundamentals of Robot Control" and "High-Voltage Comprehensive Experiments," have been offered, engaging a total of 2,543 student enrollments. By utilizing real-world engineering case studies, this methodology effectively addresses the challenge of course fragmentation.

3.1.1 Innovation of practical teaching paradigm driven by demand

Reconstructing the positioning of innovation practice education through competitions as a catalyst, elevating it from a supplementary theoretical teaching component to a core pillar driving scientific research and industrial upgrading. By implementing a mechanism of "internal disciplinary circulation (interdisciplinary integration) + external circulation (collaborative industry-university efforts) + shared platforms," a teaching paradigm is established that deeply integrates "dual-driven research-based practice" with "industry-education integration" applied practice. For example, transforming a company's "substation inspection robot" technical requirement into a competition problem stimulates updates in courses such as "Intelligent Control Algorithms," thereby organically linking the innovation chain, industrial chain, and talent chain.

3.1.2 "Organization, faculty and system" three-in-one collaborative education system

Student organization restructuring: establishing interdisciplinary innovation alliances and clubs focused on robotics, drones, and other emerging technologies; developing an advanced training framework that progresses from interest groups to project teams and competition squads; and cultivating an innovation talent pipeline comprising over 1,000 members.

Faculty Team Integration: Establishing a collaborative "University Mentor + Industry Engineer + Corporate Mentor" triad team. Fifteen university instructors and sixty-three industry experts jointly developed a comprehensive chain system encompassing competition-oriented curriculum design, course development, and project guidance, resulting in a total of 42 industry-education integration projects guided.

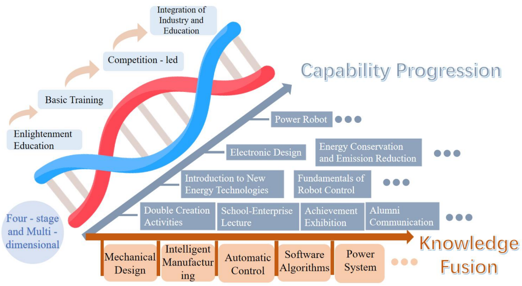

Figure 3. Diagram of the Dual-Cycle Four-Dimensional "Industry-Education Integration Platform"

Innovative institutional and mechanism reforms: establishing a dynamic response system linking "industry demand - competition topics - teaching content," co-creating a green channel for competition results transformation with enterprises, and developing an integrated industry-education base covering the entire "generation, transmission, distribution, and utilization" process to achieve seamless alignment between professional training and industry requirements.

This reform, through curriculum system restructuring and innovative collaborative mechanisms, has established an integrated training pipeline encompassing "Enlightenment - Foundation - Competition - Industry." During 2023-2024, it supported students in winning six national-level awards and 106 provincial and ministerial-level honors. Projects such as "Insulation Coating Robots" have achieved industrialization, providing a replicable practical model for cultivating innovative talents in the energy and power sector.

3.2 Effectiveness of Innovative Talent Training

3.2.1 Support of practice base and competition results

The Innovation and Entrepreneurship Practice Base operates on a 24*7 open-access basis, providing services to over 2,000 students and supporting the development and incubation of innovative projects. During 2023-2024, student teams received six national awards at the China International College Student Innovation Competition, including a Gold Award for the "Tenglong - Power Distribution Line Insulation Wrapping Robot" in 2023 and a Silver Award for the "Diting - Generator Maintenance System" in 2024. Additionally, they secured 106 provincial-level awards in mechanical innovation and other categories, demonstrating a significant enhancement in practical innovation capabilities.

3.2.2 Industry-education integration and project transformation

Students in the interdisciplinary club have participated in 42 industry-oriented projects, transforming industry demands such as power robot technology challenges into competition topics, for example, "Substation Inspection Robots." By addressing real-world engineering problems, we strengthen innovation capabilities and achieve precise alignment between the innovation chain and the industrial supply chain.

4. Promotion and Application of Project Results

4.1 Innovation and Entrepreneurship Education has been Expanded to Cover the Entire University

Through 14 courses including "Aircraft Control Technology," a total of 2,696 student participations have been achieved, establishing a closed-loop innovation and entrepreneurship education model characterized by "course dissemination - competition-led development - industry-education integration." From 2023 to 2025, over 3,000 individuals will have engaged in innovation and entrepreneurship activities, completing 16 major innovation projects (including 3 at the national level). The program has garnered 6 national-level awards and 106 provincial and ministerial-level awards, published 22 research papers, and secured 102 patents. Additionally, flagship cases such as the "Power Equipment Hospital" have been cultivated, fostering a synergistic advancement of innovative capabilities and disciplinary development.

4.2 Benchmarking of Innovative Practice Teaching Paradigm

We have established a comprehensive ecosystem encompassing curriculum development, faculty, platform, and competitions, creating a 24*7 accessible intelligent innovation and entrepreneurship hub that supports approximately 10,000 participants annually in innovative practices. The facility has been approved as a National Innovation and Entrepreneurship Education Practice Base by the Ministry of Education and recognized as a National Maker Space by the Ministry of Science and Technology, forming a replicable model of industry-education integration. Our team has published 22 SCI papers, developed specialized robots such as "Tieyu" and "Tenglong," and secured two gold and four bronze medals at the China International College Students Innovation Competition, achieving technological advancements and human replacement in high-risk operational scenarios.

4.3 Social-Industry-International Collaborative Radiation Network

Over 30 visits and inspections by leaders from the Ministry of Education and Hebei Province have established a demonstrative effect. On the societal level: promoting science popularization education among primary and secondary schools in Xinjiang and Baoding; on the industrial level: collaborating with over ten enterprises on projects such as "Yidian Technology"; on the international level: engaging in technical exchanges with 13 countries. Cases like the "Pumped Storage Power Generator Inspection Robot" have received media coverage exceeding one million views from CCTV, People's Daily, and other outlets, forming a three-dimensional radiation system encompassing technological research and development, industrial application, and social services.

5. Characteristics of Project Results

5.1 Innovation of Practical Education Ecology

Breaking through traditional teaching barriers to establish a collaborative closed-loop system of "Personnel-Organization-Platform": optimizing interdisciplinary learning organizations such as robotics through interest-driven approaches to stimulate students' intrinsic motivation; forming a "1+1+1" industry-education integration mentorship team that dissects case studies to cultivate innovative thinking; developing a fully open practical training base, supported by incentive mechanisms like innovation credits, to create a sustainable educational ecosystem.

5.2 Innovation of Practical Education Path

We pioneered the "Four-Stage Multidimensional" curriculum system, integrating multidisciplinary practical content within a four-tier structure of "Enlightenment - Foundation - Competition - Industry-Education." This approach embeds engineering case studies from the power industry into teaching, developing 14 courses and 42 industry-education projects, establishing a progressive training pathway from "knowledge-based" to "competency-based" development.

5.3 Innovation of Practical Education Paradigm

Reframe the practice-based education focus as a catalyst for scientific research and industrial advancement by implementing an "internal professional cycle + external university-industry cycle" mechanism. This approach converts corporate technological demands into competition topics and instructional content, facilitating the industrialization of projects such as the "Intelligent Safety Supervision System" and promoting the seamless integration of innovation, industry, and talent development chains.

6. Summary

Research indicates that an education model centered on competitive events significantly enhances students' innovative capabilities. However, there are notable limitations, such as insufficient depth in interdisciplinary resource integration, the need for optimization of intra- and inter-institutional multidisciplinary collaboration mechanisms, and low levels of disciplinary integration, which lead to inconsistent advancement and varying levels of success across interdisciplinary projects. The technology transfer pipeline remains underdeveloped, with a relatively low patent commercialization rate, and some competition outcomes are inadequately aligned with market demands.

The next phase will enhance interdisciplinary collaboration frameworks by establishing an intra-university cross-disciplinary resource sharing platform and regularly organizing interdepartmental project symposiums. We will accelerate the commercialization and industrialization of research outcomes by partnering with Huadian Electric Spark Innovation Space to develop an incubation platform, focusing on the market deployment of five patented technologies, including "Insulation Encapsulation Robots" and "Generator Maintenance Robots."

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