

# Tripartite Synergy in Postgraduate Education: Integrating Ideological-Political Cultivation, Industry-Academia Symbiosis, and Frontier-Driven Pedagogy in Regional Universities

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## Abstract

This paper, based on the Exemplary Teaching Case Project (ETCP) for Professional Degree Graduate Students in Henan Province, addresses three systemic deficiencies in regional graduate education: (1) the dichotomy between theory and practice in the teaching of technology; (2) the ineffectiveness of industry-teaching integration; and (3) the lagging uptake of cutting-edge technologies. This paper proposes a pedagogical framework that integrates 5G-enabled industrial internet technologies (including wireless communication principles, modern digital communication systems, and cutting-edge communication technologies) with URLLC (ultra-reliable low-latency communication) infrastructure deployed at Longmen Labs. We have constructed an interdisciplinary integration mechanism for postgraduate education, integrating ideological and political inculcation, industry practice and cutting-edge technology absorption. Through systematic case analysis and empirical investigation, nine evidence-based teaching reform propositions were put forward. A prototype deployment in CITIC Heavy Industry's smart manufacturing sector demonstrated its operational effectiveness, thereby establishing a replicable framework for regional higher education transformation.

## Keywords

Graduate education; 5G industrial internet; Industry-teaching integration; Civic education; Cutting-edge technology.

## 1. Relevant Background

### 1.1. The Era's Demand for Educational Reform

President Xi Jinping emphasized at the National Education Conference that "we must deepen educational reform and improve the mechanisms for implementing moral education[1]." This significant statement establishes the fundamental guideline for graduate education reform in the new era. Currently, the global manufacturing industry is undergoing profound changes centered on intelligence and networking[2]. As a product of the deep integration of new-generation information technology and manufacturing, the industrial internet holds strategic significance for supporting the construction of a manufacturing powerhouse. Against this backdrop, the demand for high-level technical talents capable of managing complex industrial network architectures and ensuring real-time reliable transmission continues to expand, especially for professionals proficient in key technologies such as time-sensitive networks.

Authoritative forecasts predict that by 2025, the talent gap in this field will reach 2.54 million, with interdisciplinary talents possessing systematic thinking abilities being particularly scarce. This structural contradiction between talent supply and demand fundamentally exposes the disconnect between traditional training models and the speed of industrial transformation. For example, in the field of industrial networks, the existing curriculum system still focuses on traditional network protocol teaching, with limited coverage of core technologies like time-sensitive networks that support industrial control real-time performance. The lag in educational content results in graduates generally lacking the ability to design deterministic transmission channels in intelligent manufacturing scenarios, thus making it difficult to meet the stringent 10ms-level latency control requirements of smart factories. To resolve this dilemma, it is crucial to establish a dynamic adaptation mechanism between educational supply and industrial demand.

Graduate education, as the core pillar of the national innovation system, demonstrates its strategic value in three aspects:

1. In the innovation-driven development strategy, the graduate group undertakes 62% of the tasks in the national key R&D programs. Notably, in the "Eastern Data Western Computing" national project, 90% of the leaders of core algorithm R&D teams hold graduate degrees.

2. Facing new challenges brought by generative AI technologies like ChatGPT, ideological and political education for graduate students encounters new demands. The "Guidelines for the Construction of Ideological and Political Courses for Graduate Students," jointly issued by eight departments including the Ministry of Education, clearly require the integration of ideological and political elements such as "scientific ethics" and "craftsmanship spirit" into professional courses. Research by Tsinghua University in 2023 indicates that graduate students with a clear sense of serving the country through scientific research have a 37% increase in productivity.

3. The urgency of industry-education integration is increasingly prominent. The "2024 White Paper on Electronic Information Talent Cultivation" issued by the Guangdong Provincial Department of Education points out that the matching degree between enterprise technical needs and university training programs is less than 50%. Data from Zhejiang Province's "Industry-University-Research Collaborative Training Demonstration Base" shows that the retention rate of jointly trained graduate students in enterprises is 29 percentage points higher than that of traditional models.

## 1.2. Progress in Teaching Reform Practices

China's graduate education reform has entered a deepening stage, forming several typical models: Jiangsu Province's "Industry Professors" system, which selected 500 enterprise experts in 2023 to co-build a curriculum module library, achieving 100% integration of real enterprise projects into classrooms. Guangdong Province's "Bay Area Excellent Engineer" program piloted the "3+3" training model at South China University of Technology, which won the National Teaching Achievement Special Prize in 2023. Zhejiang Province, relying on ZhiJiang Laboratory, has constructed a "project-based" training system, with 68% of graduate students participating in Alibaba DAMO Academy projects. These reform practices indicate that the industry-university collaborative training model can enhance graduate engineering practice abilities by 42%-65%.

Despite achieving phased results, graduate education currently faces three contradictions:

(1) The organic integration of value guidance and technological innovation has not yet been formed.

(2) There is a generational gap between practical teaching links and real industrial scenarios.

(3) The speed of curriculum updates lags behind the technology iteration cycle. These issues are particularly prominent in frontier technology fields like time-sensitive networks, severely restricting the quality of talent cultivation.

This paper focuses on these key bottleneck issues and strives to construct an innovative training model that integrates ideological and political education, scientific research, and frontier technologies, providing a systematic solution to the dilemma of cultivating high-level talents for the industrial internet.

## 2. Analysis of Issues in Graduate Education at Local Universities

### 2.1. Disconnection Between Ideological Education and Research Competence Development

#### Issue 1: Disjointedness Between Ideological Courses and Professional Teaching[3]

A prevalent issue in current graduate education is the systemic separation between value guidance and professional technical training. Ideological courses often adopt a centralized teaching model, focusing on macro policy interpretation and moral theory, while professional courses emphasize technical principles and engineering methods[4]. This separation makes it challenging for students to establish an intrinsic connection between scientific ethics and engineering practice. Specifically, during technological breakthroughs, there is a lack of consideration for social values; in research topic selection, national strategic needs are overlooked; and in the transformation stage of results, public welfare assessments are weakened. Fundamentally, the educational system has failed to establish a bidirectional mapping mechanism between 'values and technology,' hindering the deep integration of socialist core values throughout the technological innovation process. To address this disconnection, it is necessary to establish a coupling model between ideological elements and professional knowledge, achieving an organic unity of value guidance and technological innovation through case-based and scenario-based teaching designs.

#### Issue 2: Emphasis on Technology Over Ethics in Research Projects

In the process of cultivating practical abilities, engineering ethics education often remains at the level of abstract concept explanation, without being embedded in real research contexts. The existing evaluation system excessively emphasizes technical indicators, such as algorithm accuracy improvement and system latency optimization, with quantitative parameters occupying more than 80% of the assessment weight. In contrast, qualitative aspects, such as ethical risks and the social impacts of technological applications, lack systematic evaluation standards. This value orientation bias leads to a prevalent "technological supremacism" tendency among graduate students, manifested in:

- (1) Ignoring privacy protection boundaries when pursuing technological innovation.
- (2) Weakening environmental cost accounting when optimizing engineering efficiency.
- (3) Lacking algorithm fairness review when developing intelligent systems.

To reconstruct the ethical education paradigm, it is essential to integrate a sense of responsibility throughout all stages of research practice, establishing a dual evaluation framework of "technical feasibility and ethical compliance."

### 2.2. Inadequate Industry-Academia Collaboration Mechanisms

#### Issue 3: Superficial School-Enterprise Cooperation

Current school-enterprise collaborative training exhibits significant institutional deficiencies. Cooperation agreements often focus on hardware resource sharing and talent delivery channels, lacking deep integration mechanisms at the level of knowledge production. The role of enterprise mentors is often ambiguous, typically limited to equipment operation guidance

and internship discipline management, without involvement in curriculum development and course system design. This superficial cooperation model results in practical teaching exhibiting "three characteristics":

(1) Fragmented training content, unable to form a complete technical capability map.

Virtualized project tasks, detached from real industrial problem scenarios.

(2) Standardized evaluation criteria, neglecting the economic and maintainability aspects of engineering systems.

To construct a deep collaborative mechanism, it is necessary to break organizational boundaries, establishing curriculum development committees and quality monitoring systems with joint participation from both schools and enterprises.

#### **Issue 4: Training Objectives Lagging Behind Industrial Upgrading**

Professional degree graduate education faces a structural contradiction between accelerated technological iteration and the lagging pace of curriculum updates. The revision cycle of existing training programs is typically 3-5 years, unable to match the annual technological evolution speed of over 20% in fields like industrial internet and intelligent manufacturing. Textbook content often focuses on classical theoretical systems, with insufficient coverage of cutting-edge technologies such as 5G URLLC and TSN time-sensitive networks[5]. This lag leads to a generational gap between graduates' knowledge structure and enterprises' real-world needs, specifically:

Mastery of traditional network architectures but lack of deterministic communication design capabilities.

Familiarity with classical control theories but ignorance of digital twin system integration methods.

To resolve this contradiction, it is necessary to establish a dynamic curriculum adjustment mechanism, forming a rapid response chain of "technology monitoring, content transformation, and teaching implementation."

### **2.3. Lagging Integration of Cutting-Edge Technologies**

#### **Issue 5: Slow Update of Teaching Content**

The traditional curriculum system exhibits significant technological disconnection. Core course knowledge modules are fixed, often centered around mature technologies, lacking systematic explanations of new technologies widely applied in industrial sites, such as TSN traffic shaping and FRER frame redundancy elimination[6]. Experimental teaching relies on standardized equipment platforms, unable to replicate the multi-protocol heterogeneous network environments in real industrial scenarios. This lag leads to students' technical cognition remaining at the theoretical level, unable to cope with actual engineering challenges faced by enterprises. For example, in intelligent factory deployments, students may be unable to handle cross-domain clock synchronization issues, and in industrial internet operations and maintenance, they may lack deterministic service quality assurance capabilities. To promote teaching content innovation, it is necessary to construct a mapping transformation model of "industry technology inventory to course knowledge map," achieving precise alignment between educational supply and technological demand[7].

#### **Issue 6: Disconnection Between Laboratories and Industrial Scenes**

University laboratory environments often exhibit a tendency towards "technological simulation and idealized scenarios." Existing training platforms often use simplified industrial equipment, filtering out complex factors such as noise interference and protocol conflicts in real production systems. As shown in Figure 1, real industrial scenarios require constructing multi-faceted protection systems, including equipment safety, control safety, network security, application security, and data security, which significantly differ from the single-point security

testing environments in laboratories[8]. This de-contextualized design leads to students forming "laboratory capability illusions," specifically:

- (1) Completing standard testing tasks in controlled environments but unable to diagnose mixed traffic congestion issues when facing enterprise production line equipment.
- (2) Lacking systematic thinking when handling multi-vendor equipment interoperability failures.

To break this predicament, it is necessary to introduce new technologies such as digital twins and metaverse to construct a virtual-real integrated training environment, enhancing technical transfer capabilities through high-fidelity industrial scenario reproduction.

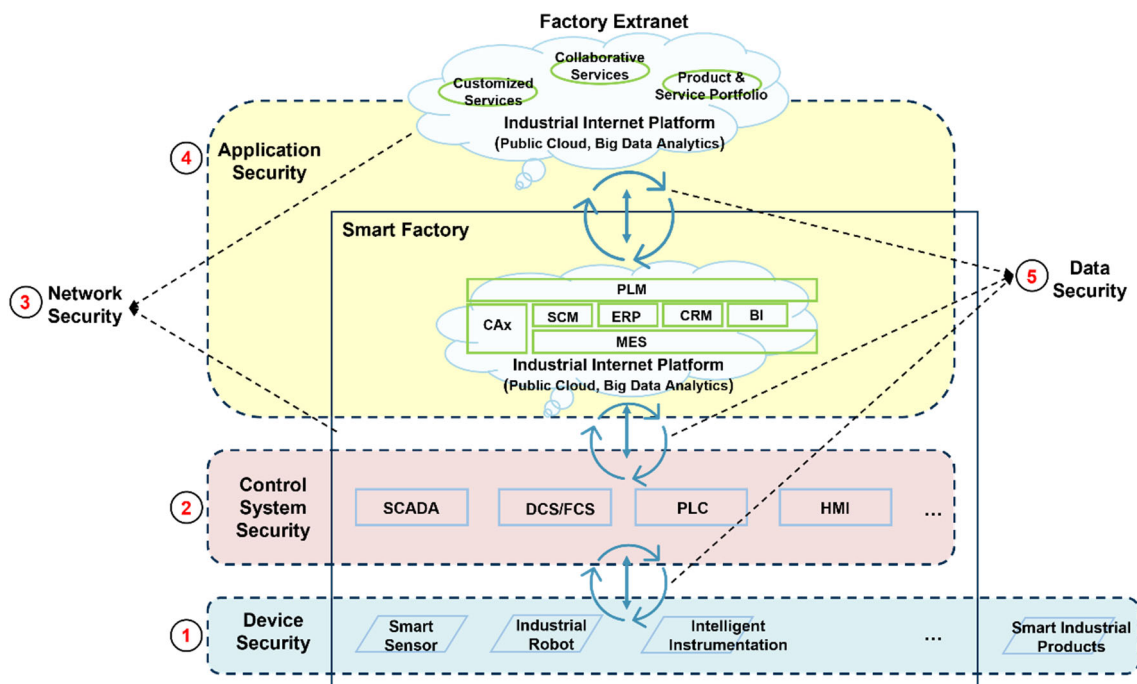


Figure 1. Low Latency High Reliability Network Security Architecture

### 3. Integrated Training Model Solutions

#### 3.1. Ideological Education+Research: Integrating Value Orientation and Technological Innovation

##### Issue 1: Integrating Spiritual Inheritance with Case-Based Teaching

We propose the creation of a new ideological education paradigm characterized by "role model guidance - immersive engagement - value internalization." By analyzing the technological breakthroughs achieved by the Huang Danian team in deep-earth exploration equipment development, we design seminars centered around the theme of "Contributing to the Country through Scientific Research," guiding students to analyze the underlying spiritual motivations behind critical technological advancements. In the case of 5G-TSN network optimization, we incorporate a module that examines the relationship between equipment power consumption reduction and carbon emission[9], encouraging students to simultaneously consider both technical performance and societal benefits during parameter optimization. This educational design facilitates three key transformations: from abstract rhetoric to concrete demonstration, from passive reception to active construction, and from value recognition to conscious action, thus effectively addressing the superficiality of ideological education.

##### Issue 2: Interweaving Technical Practice with Ethical Reflection

In the 5G-TSN networking experimental curriculum, we innovatively integrate dual-thread tasks of "technology and ethics." Students are required not only to achieve traditional technical objectives, such as network latency optimization, but also to engage in group debates on ethical issues, such as data acquisition scope and user privacy boundaries. For example, in industrial vision system deployment, we set up conflict scenarios that involve "efficiency improvement versus worker rights protection," guiding graduate students to use multi-criteria decision analysis to find a balance. This approach cultivates a sense of professional responsibility, ensuring that ethical considerations are incorporated into the feasibility evaluation stage of technical solutions, thereby proactively preventing the risks of technological ethics violations.

### **Issue 3: Engaging Industry Role Models with Academic Growth**

We propose the creation of a sustainable mechanism for "model workers and craftsmen entering the classroom," systematically designing lecture series in fields such as equipment manufacturing and information communications. By inviting chief technicians from CITIC Heavy Industries to discuss the "craftsmanship spirit" involved in overcoming key technological challenges, we explore the practical value of dedication and precision. Through on-site demonstrations of technical details, such as the development process of shield machine main bearings, students gain a profound understanding of the critical role that professional attitudes, such as dedication and excellence, play in achieving technological breakthroughs. This hands-on approach to education breaks the temporal and spatial limitations of traditional ideological education, facilitating the integration of value transmission into the dissemination of technical knowledge.

## **3.2. Industry-Academia Synchronization: Dual Mentorship System and Scenario-Based Training**

### **Issue 4: Capability Construction Driven by Real Tasks**

In collaboration with ZTE Communications, we have developed a comprehensive practical teaching framework, comprising the "problem chain - task series - capability set" model. Using the configuration of 5G industrial gateways as a typical task, we decompose real enterprise requirements into sub-tasks such as equipment selection, protocol adaptation, and fault diagnosis. Students work in teams to complete the entire workflow from demand analysis to deployment and maintenance, with enterprise mentors focusing on guiding decision-making processes under multi-constraint conditions. This model transcends traditional experimental teaching, enabling students to develop an engineering mindset oriented toward uncertainty when addressing complex issues such as equipment heterogeneity and protocol compatibility.

### **Issue 5: Cognitive Iteration Mechanism Through Segmented Training**

We propose a spiral training path that progresses through "laboratory cognition - enterprise verification - reflection and improvement." In the first three semesters, students complete foundational technical training in areas such as TSN traffic shaping, while in the final three semesters, they participate in production-line-level practices within companies like CITIC Heavy Industries. Each stage has clear objectives for skill development, from basic equipment debugging to system integration and from standard protocol implementation to customized development. This segmented mechanism addresses the randomness often found in traditional internships and enables the continuous iteration of "technical cognition - application verification - experience abstraction," thus facilitating the systematic enhancement of engineering practice capabilities.

### **Issue 6: Multi-Dimensional Evaluation Guiding Quality Transformation**

We introduce an innovative three-dimensional evaluation system based on "technology - business - ethics." Enterprise mentors evaluate projects from the perspectives of technical feasibility, cost control, and maintenance ease; academic mentors focus on assessing theoretical

innovation and academic rigor, while third-party experts are tasked with reviewing the social impact and ethical considerations of the project. For instance, in an intelligent factory simulation project, the evaluation focuses not only on the precision of digital twin models but also on assessing the predictive validity of the project's impact on employment structure. This evaluation mechanism fosters a holistic quality consciousness among students, shifting the focus of training objectives from simply meeting "technical standards" to fostering "value creation."

### 3.3. Cutting-Edge Technology Driven: Dynamic Curriculum Updates and Interdisciplinary Practice

#### Issue 7: Technology Evolution Response Mechanism

We propose a dual-cycle system involving "industry dynamic monitoring and curriculum content adaptation." This involves the formation of a technical observation group composed of industry experts and members of technical standards organizations, who will release quarterly reports on the evolution of 5G industrial internet technologies[10]. The teaching committee will then update the curriculum modules accordingly, such as introducing TSN traffic shaping experiments to replace traditional Quality of Service (QoS) units. By maintaining continuous alignment between the curriculum and technological advancements, this approach ensures that students master current industry solutions, such as FRER anti-fading techniques, instead of relying solely on textbook algorithms. As shown in Figure 2, the air interface delay optimization is achieved through a three-layer architecture design of PDCP replication at the radio access layer, TSN gateway protocol conversion at the core network, and DetNet+FRER redundancy elimination at the edge side[11].

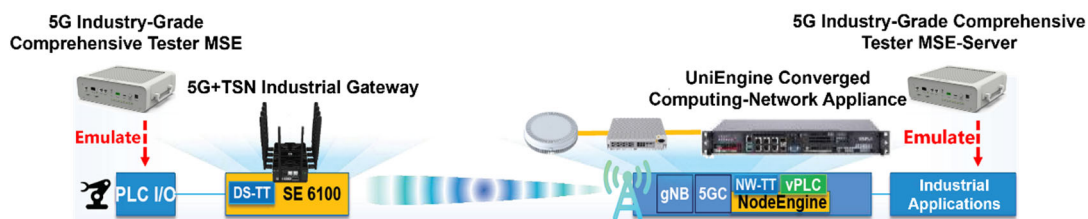


Figure 2. 5G Industrial Internet Test Platform

#### Issue 8: Complex System Thinking Cultivation Path

We propose designing interdisciplinary, "full-chain" collaborative projects that involve "multi-disciplinary - deep integration." For instance, in the development of an intelligent factory digital twin system, mechanical engineering students are responsible for physical entity modeling, computer science students design virtual mapping systems, and electronics and information students implement 5G-TSN network interconnectivity[12]. During collaborative development, students must understand the technical constraints and value orientations of each discipline, such as the coupling relationship between mechanical precision and communication latency. This approach cultivates system-level engineering thinking, equipping students with the ability to manage complex systems where "mechanical - electrical - communication" integration is essential.

#### Issue 9: Virtual-Real Integrated Experimental Innovation

We propose the establishment of a new experimental platform that integrates "digital twin technology and physical equipment interaction[13]." By using high-precision modeling to replicate multi-robot collaboration scenarios from CITIC Heavy Industries, students can test different network configurations in a virtual environment and verify them by controlling physical devices via 5G-MEC edge computing systems[14]. This "simulation - verification -

optimization" closed-loop training model not only overcomes the safety limitations of traditional laboratories but also maintains the technical complexity of real-world industrial scenarios, enabling students to acquire production-line problem-solving capabilities in a controlled, risk-free environment.

## 4. Conclusion

The integrated training model of 'Ideological Education Guidance, Industry-Academia Integration, and Cutting-Edge Technology Drive,' proposed in this study, facilitates paradigm shifts across three dimensions: In terms of value shaping, it establishes a progressive ideological education pathway that transforms the abstract notion of "serving the country through science and technology" into a guiding principle for engineering practice; in the dimension of capability cultivation, it creates a spiral mechanism of "technology development - scenario validation - system optimization," addressing the traditional gap between theory and practice; and in terms of knowledge supply, it introduces a dynamic response system based on "technology monitoring - curriculum adaptation - ecosystem construction," effectively bridging the generational gap between educational content and industry frontiers.

In pilot practices with companies such as CITIC Heavy Industries[15], this model has demonstrated significant adaptability. Graduate students exhibit stronger systems thinking and a heightened sense of technological ethics when solving complex engineering problems, such as multi-robot collaboration control.

Since the deepening of education and teaching reform in the School of Information Engineering of Henan University of Science and Technology, the scientific research achievements have been remarkable[16]. According to the statistics of Web of Science official website, since the implementation of graduate training mode, teachers and students have published 87 papers together. Among them, 54 papers were published in JCR Q1 and Q2 journals, accounting for 62.06% of the total. The achievement of these results is inseparable from the three-level linkage training system of "discipline-specialization-course" implemented by the university.

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