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Strategies for Cultivating Vocational Bachelor Talents Based on Employment Demands: A Case Study of Civil Engineering Major

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Abstract: At a crucial stage in China's construction industry transformation towards green, industrialized, and digital development, vocational bachelor education undertakes the important mission of cultivating high-level technical and skilled talents. Taking the civil engineering major as an example, this paper focuses on the employment demands of the industry and systematically explores the strategies for cultivating vocational bachelor talents. First, by analyzing the impact of industrial transformation on the talent competency structure, it clarifies the core positioning of vocational bachelor talents in the three dimensions of "technical implementation, on-site management, and technical optimization." Second, it constructs a modular curriculum system of "basic sharing + direction diversion + project penetration" to promote the synchronous updating of curriculum content and industry technology. Finally, it proposes a "three-level progressive" practical teaching system and a deep integration mechanism of industry and education, and establishes a diversified evaluation model with competency achievement as the core. Research shows that only by building a demand-oriented, deeply integrated industry-education dynamic education system can the adaptability of talent cultivation be effectively improved, providing a solid support for the modernization of the construction industry.

1. Introduction

With the continuous deepening of economic structural transformation and industrial upgrading in China, the construction industry is undergoing a historic shift from a traditional labor-intensive model to a modernized construction model characterized by deep integration of green practices, industrialization, and digitalization. This transformation has not only spurred the emergence of new fields such as intelligent construction, prefabricated buildings, and green construction, but also placed an urgent demand on the industry to systematically reshape the skill sets of its workforce[1]. Against this backdrop, vocational bachelor's education, as a crucial link between higher vocational education and undergraduate education, has been entrusted with the strategic mission of cultivating high-level technical and skilled personnel and serving the high-end development of industries. However, current vocational bachelor's education, particularly in traditional engineering fields such as construction engineering, still faces significant challenges in its talent development system: misalignment between training objectives and actual industry needs, curriculum content lagging behind the pace of technological iteration, and disconnection between practical teaching and production processes[2]. This leads to graduates struggling to quickly adapt to the high-level requirements of complex technology integration and process innovation demanded by the job market.

Therefore, exploring and constructing a vocational bachelor's talent development system that takes the real needs of the industry as its fundamental starting point and can dynamically adapt to technological changes has become a key issue in promoting the high-quality development of the construction industry and the construction of a modern vocational education system[3]. This research focuses on the typical field of construction engineering, aiming to systematically address the core questions of "who to cultivate" and "how to cultivate." The research will follow the logical thread of "needs analysis, objective positioning, system reconstruction, practical innovation," first deeply analyzing the specific changes and core characteristics of the demand for technical and skilled personnel in the context of the transformation and upgrading of the construction industry. Based on this, it will accurately define the unique training positioning and competence model of vocational bachelor's level talents. Furthermore, it will propose targeted reconstruction plans for a modular curriculum system and practice teaching innovation paths oriented toward industry-education integration. Ultimately, it will form a set of operable and scalable closed-loop strategies for vocational bachelor's talent development based on deep industry-education integration. This research will not only help provide theoretical references and practical guidance for the connotative development of vocational bachelor's education in construction engineering, but its methodology of demand-oriented, competency-based, and integration-driven approach can also provide valuable paradigm references for the construction of other engineering vocational bachelor's programs, and has important practical significance for resolving the structural contradiction between the supply side of talent development and the demand side of the industry.

2. Industry Demand Analysis and Talent Development Goal

2.1 Transformation Trends in the Construction Industry

Currently, China's construction industry has entered a new stage themed with high-quality development. The transformation trend is concentrated in the coordinated promotion and deep integration of "green building," "intelligent construction," and "building industrialization." This process not only changes production tools and management models, but also fundamentally reshapes the industry's demand for the capabilities and hierarchical structure of technical skill talents[4].

From a macro trend perspective, the deepening of the green building concept requires practitioners to go beyond simple energy-saving design and possess the ability to calculate and control carbon emissions throughout the entire life cycle, knowledge of green building materials and renewable energy systems application, and the comprehensive ability to create a healthy building environment. The rapid development of intelligent construction is driven by digital technologies such as Building Information Modeling (BIM), the Internet of Things, big data, and artificial intelligence, promoting the digital management of the entire process of design, production, construction, and operation and maintenance. This requires talents to not only be able to operate related software, but also possess cross-professional information collaboration capabilities, data-driven decision-making capabilities, and an understanding and basic application capabilities of intelligent construction equipment (such as construction robots and intelligent monitoring equipment). Building industrialization, especially the popularization of prefabricated buildings, transfers a large amount of on-site wet operations to factories, making the production process tend to be manufacturing-oriented, thus placing unprecedented high demands on talents' ability to deepen the design of prefabricated components, precise installation, node connection quality control, and industrial construction organization and management.

Based on the above trends, through in-depth research and analysis of domestic large-scale construction enterprises, leading design institutes, and engineering consulting management companies, the core needs of vocational undergraduate-level talents in the field of construction engineering can be focused on three typical job groups: construction technology management, detailed design and digital application, and engineering project management. In construction technology management positions, what companies urgently need is no longer just "operators" who can only construct according to drawings, but "on-site technical leaders" who can understand and apply new technologies and processes, solve complex technical problems on-site, organize and implement special construction plans, and optimize and improve traditional processes[5]. They need to be proficient in the construction technology of prefabricated buildings, green construction technology measures, and have the preliminary ability to apply BIM models on-site. In detailed design and digital application positions, with the popularization of BIM technology and the development of design-construction integration (EPC) model, there is a strong market demand for "BIM engineers" or "detailed designers" who understand engineering professional technology and can skillfully use BIM and other digital tools for collision checking, construction simulation, quantity surveying, and pipeline integrated optimization.

2.2 Positioning of Vocational Undergraduate Talent Cultivation

Vocational undergraduate education, as a type of vocational education at the undergraduate level, must have a talent cultivation positioning that is clearly distinct from general undergraduate engineering education and higher vocational college education, forming its own irreplaceable characteristics and advantages. Its core characteristic lies in being demand-driven by vocational needs, focusing on the cultivation of practical abilities, and using industry-education integration as a means to cultivate high-level technical skilled personnel who can be competent in complex technical operations and carry out process improvements and technological innovations.

Compared to general undergraduate education, vocational undergraduate programs in construction engineering should weaken overly profound theoretical derivations and academic research orientations, and instead strengthen the "application scenarios" and "technology transformation" of theory. The logical chain of vocational undergraduate education is "theory → technology/craft → direct implementation and optimization." It emphasizes that students directly apply engineering principles and technical knowledge to solve practical complex problems in the front lines of production, construction, management, and service, especially demonstrating outstanding abilities in optimizing construction techniques, formulating technical solutions, and making on-site technical decisions, namely, the "technology integration" and "process innovation" abilities mentioned earlier.

Compared to higher vocational college education, vocational undergraduate education should achieve vertical elevation and horizontal expansion in its training objectives. Higher vocational colleges mainly cultivate high-quality skilled personnel who are proficient in operating specific equipment and executing established procedures, with their positions facing relatively specific and singular tasks. Vocational undergraduate programs, on the other hand, emphasize the understanding of complex technical systems, the ability to apply multiple technologies in an interdisciplinary manner, and preliminary technical management responsibilities. For example, higher vocational college students may be proficient in operating total stations for surveying and setting out, while vocational undergraduate students should be able to be responsible for the formulation, organization, implementation, and error analysis of measurement plans for a construction section or special project[6]. Higher vocational college students can complete the hoisting of prefabricated components according to regulations, while vocational undergraduate students should be able to prepare the installation plan for the sub-item project, handle unconventional technical problems in the installation process, and coordinate related trades. Therefore, vocational undergraduate talents possess stronger technical absorption, digestion, application, and re-innovation capabilities, as well as broader career development potential and job migration capabilities.

Based on this positioning, the competency model for vocational undergraduate talents in construction engineering can be constructed as three closely related and mutually supportive dimensions: the technical implementation dimension, which means mastering the core technologies and processes of modern construction engineering and having the ability to solve complex technical problems on site; the on-site management dimension, which means having the ability to preliminarily coordinate and control the technology, quality, safety, progress, and resources of small and medium-sized projects or special projects; and the technical optimization dimension, which means having the awareness and preliminary ability to locally improve and optimize existing construction methods and process flows based on new technologies, new processes, and new materials. These three dimensions together constitute the unique competency profile of vocational undergraduate talents that distinguishes them from talents at other levels.

2.3 Cultivation Objectives for Vocational Undergraduate Talents in Construction Engineering

The objectives of talent cultivation must shift from general descriptions to specific, measurable, and achievable goals, effectively aligning with industry standards and professional qualifications. The overall objective of vocational undergraduate talent cultivation in construction engineering can be expressed as: Cultivating well-rounded individuals with comprehensive development in moral, intellectual, physical, aesthetic, and labor education; adapting to the modern development needs of the construction industry; mastering a solid foundation of basic theories and specialized knowledge in construction engineering; possessing outstanding engineering practice capabilities, technical innovation literacy, and preliminary project management skills; and being able to engage in high-level technical and skilled work such as construction technology management, detailed design and digital applications, and engineering project management in fields such as building construction and municipal infrastructure.

Furthermore, a hierarchical and categorized goal-setting mechanism should be established to address the differentiated needs of the industry for talents in projects of varying scales and types. For the cultivation of technical backbones for small and medium-sized projects, the objective should emphasize "versatility" and independent responsibility, enabling them to serve as core technical members of project teams, undertaking the main technical responsibilities from technical preparation to on-site implementation. For the cultivation of specialized technical positions in large and complex projects or emerging fields (such as super high-rise steel structure construction, intelligent operation and maintenance of integrated pipe corridors, and building energy-saving renovation), the objective should focus on in-depth knowledge and skills in specific technical areas, emphasizing students' mastery of a particular specialized technology and their ability to solve high-difficulty problems in that field, enabling them to quickly integrate into professional teams of large projects and become an indispensable specialized technical force. This hierarchical and categorized goal setting ensures the diversity of talent cultivation and the adaptation to industry needs, providing clear guidance for students' personalized development and precise employment.

3. Modular Curriculum System Reconstruction Based on Competency Matrix

The curriculum system is the core carrier for achieving talent development goals. When facing the rapid transformation and upgrading of the industry, the traditional construction engineering curriculum system increasingly reveals systemic drawbacks such as rigid structure, outdated content, and disconnection between theory and practice. In order to accurately align with the competency model established in Chapter 1, which takes "technical implementation, on-site management, and technical optimization" as the core dimensions, this chapter proposes a modular, project-based, and dynamic reconstruction of the curriculum system based on a competency matrix. This system aims to break down disciplinary barriers and achieve a direct mapping of knowledge, skills, and industry needs, cultivating high-level technical and skilled personnel who can master the complexities of modern construction engineering.

3.1 Problem Analysis of Traditional Curriculum System

Currently, the curriculum systems of construction engineering programs in many institutions still originate from the disciplinary system framework of ordinary undergraduate programs. Although they have undergone local adjustments, deep structural problems remain prominent, making it difficult to meet the vocational undergraduate education's requirements for technical integration and innovative application capabilities. The primary problem lies in the severe disconnection between theoretical teaching and practical application. The course arrangement often follows a linear sequence of "public basic courses → professional basic courses → professional courses," and the practical links are mostly attached to theoretical teaching in the form of verification experiments and centralized internships. This leads to students lacking perception of engineering contexts when learning abstract theories, and difficulty effectively calling and deepening theoretical knowledge when engaging in practice, forming a "separation of learning and application" dilemma. Secondly, there is a significant lag in course content compared to industry technology development. Textbook updates are slow, and teaching content often focuses on mature traditional technologies, with insufficient and untimely introduction of cutting-edge technologies such as green buildings, intelligent construction, and prefabricated buildings, as well as new industry norms, new processes, and new materials. This results in a "generation gap" between the knowledge and skills mastered by graduates and actual industry applications, requiring companies to invest significant resources in secondary training. This fragmented knowledge structure seriously restricts the formation of students' ability to cope with systemic and complex problems in modern engineering[7].

3.2 Curriculum Structure Design

To address the aforementioned issues, a new modular curriculum structure oriented towards capability output and flexibly responsive to industry needs must be constructed. This paper proposes a three-layer architecture of "foundation sharing, directional diversion, and project integration," aimed at strengthening the foundation, highlighting characteristics, and integrating knowledge.

The foundation sharing module serves as the cornerstone for students' professional capability development. Its goal is not to pursue theoretical completeness and depth, but rather to emphasize the "application-oriented" and "service support" functions of engineering principles. Core foundation courses such as "Engineering Mathematics," "Structural Mechanics," and "Engineering Materials" are restructured, with content carefully selected to closely align with the needs of subsequent professional courses and engineering practice. The directional diversion module is key to reflecting the characteristics of vocational undergraduate education and connecting with subdivided fields of industry. After students complete solid foundation sharing module learning, several cutting-edge technology direction course packages are set up according to industry development trends and student interests. For example, an "Intelligent Construction Direction Package" can be established, including courses such as "BIM Technology and Collaborative Design," "Internet of Things and Intelligent Construction Monitoring," and "Fundamentals and Applications of Construction Robots"; a "Prefabricated Building Direction Package," including courses such as "Prefabricated Component Design and Detailing," "Prefabricated Building Construction Technology and Quality Control," and "Prefabricated Building Project Management"; and a "Green Building and Energy-Saving Engineering Direction Package," including courses such as "Building Energy-Saving Technology and Materials," "Building Carbon Emission Calculation and Evaluation," and "Green Construction and Operation Management." The course content within each course package is deeply integrated with the vocational standards, typical work processes, and core technologies of the corresponding fields, ensuring that students can form in-depth technical skills and competitive advantages in specific fields[8].

The project integration module is the main thread for integrating knowledge and cultivating comprehensive abilities. It is not a separate course, but a teaching organization form that integrates a series of progressive comprehensive projects throughout the entire academic program. These projects originate from or highly simulate real engineering projects, covering the main stages of design, construction, and management. The theoretical knowledge and skills training of related courses are centered around the stage tasks of these projects. Through project integration, students actively integrate multi-disciplinary knowledge in increasingly realistic engineering situations, continuously exercise the ability to implement technology, collaborate on tasks, and solve complex problems, thereby effectively breaking down disciplinary barriers.

3.3 Synchronized Update Mechanism for Curriculum Content and Industry Technology

The effectiveness of a modular structure depends on the curriculum content being dynamically synchronized with advancements in industry technology. A stable and efficient school-enterprise collaborative mechanism for updating curriculum content must be established.

First, industry standards and technical regulations should be systematically introduced and used as the fundamental basis for selecting and updating curriculum content. Key provisions of current national and industry standards, such as the "Standard for Construction Technology of Building Engineering," "Technical Specification for Assembled Concrete Structures," and "Construction Application Standard for Building Information Modeling," should be directly incorporated into textbooks and lesson plans. The design of teaching cases, exercises, and project tasks should strictly adhere to these standard specifications, so that students develop the professional habit of "operating according to standards and acting in accordance with specifications" while in school. Second, school-enterprise collaborative development of loose-leaf textbooks, workbook-style textbooks, and digital teaching resource libraries is an effective way to overcome the shortcomings of the long update cycle of traditional textbooks.

Finally, a fast track for "industry technology dynamics → teaching case transformation" should be established. Professional teachers should be encouraged to closely follow industry dynamics through enterprise practice, technical services, and other means, and to promptly transform real technical problems, process improvement examples, and management innovation practices that they participate in or learn about into classroom discussion questions, course design topics, or graduation design projects. At the same time, technical managers and skilled workers from enterprises should be regularly invited into the classroom to hold special lectures or conduct short-term workshops, directly conveying the most up-to-date industry experience and thinking to students, and achieving "zero-time difference" alignment between curriculum content and the front line of the industry.

4. Innovation and Evaluation Reform of Practice Teaching System

Practice teaching is the core characteristic that distinguishes vocational undergraduate education from general undergraduate education. It is a key link for the internalization, transfer, and innovation of technical skills, and it is also the fundamental way to realize the leap from "knowing" to "doing" in talent cultivation. Practice teaching based on the traditional discipline system often has problems such as fragmentation, simulation, and lagging behind the production site, which makes it difficult to support the training goals of high-level technical and skilled talents. Therefore, it is necessary to take deep industry-education integration as the fundamental orientation, carry out systematic innovation of the practice teaching system, and implement evaluation reform with ability achievement as the core. This will construct a closed-loop system of "teaching environment aligned with the production environment, teaching process aligned with the work process, and teaching evaluation aligned with job competency standards," ensuring that students have the preliminary ability to solve complex technical problems on the front line upon graduation.

4.1 "Three-Tier Progressive" Practical Teaching System Design

To systematically cultivate students' engineering practice capabilities, it is necessary to break the original discrete model of experiments and practical training attached to courses. A three-tier progressive practical teaching system should be constructed with clear goals, distinct levels, and gradual progression: "Basic Skills Layer, Comprehensive Application Layer, Innovative Practice Layer." This system uses real engineering projects as carriers and complete work processes as logic, progressively enhancing students' skill complexity, problem comprehensiveness, and innovation participation.

The Basic Skills Layer is aimed at freshmen and sophomores, focusing on single core skill operations and standard habit formation in the field of construction engineering. Its main carriers are professional basic laboratories and skill training centers within the university. The goal of this level is "proficiency and standardization," that is, through repeated and standardized training, students master the correct usage methods of key tools and instruments, and the operational processes of basic techniques. This stage emphasizes the standardization of operations, the accuracy of results, and the initial development of professional qualities, laying a solid "basic skill" foundation for subsequent comprehensive applications.

The Comprehensive Application Layer is aimed at sophomores and juniors, and aims to cultivate students' ability to integrate knowledge from multiple courses to solve comprehensive engineering problems. Its core is to organically connect the theoretical learning and practical training of multiple professional core courses through "course design" and "specialized practical training." The key to this level is "simulation" and "real project driven." For example, around a real "small and medium-sized frame structure community service center" project, a series of course designs for "Building Structures" and specialized practical training for "BIM Technology Comprehensive Application" can be carried out. These design tasks are interlocked, and the latter task needs to be based on the results of the previous task, simulating the collaborative workflow of design-construction-cost management. In this process, students need to independently consult materials, formulate plans, collaborate in teams, and deal with various contradictions and conflicts encountered in the design, so as to integrate discrete knowledge points into the ability to solve systemic problems.

The Innovative Practice Layer is aimed at juniors and seniors and is the highest stage of practical teaching. The goal is to cultivate students' awareness of technological innovation and preliminary research and development capabilities, and to realize the potential transformation from "skill appliers" to "technology improvers." This level must rely on real industrial environments and cutting-edge technical issues, and its best platforms are "technology research and development centers," "industry colleges," or "teacher enterprise workstations" jointly built by universities and enterprises. At this stage, students directly participate in enterprises' real technical problem-solving, process optimization, or application research and development projects as "quasi-employees" or "project team members." The Innovative Practice Layer not only provides the most realistic and complex learning situation, but more importantly, it stimulates students' internal motivation to explore the principles of engineering technology and seek better solutions. It is a key link to realize the "technology optimization" ability dimension of vocational undergraduate talents.

4.2 Deepening the Mechanism of School-Enterprise Cooperative Education

The effective operation of the "three-level progressive" practical teaching system, especially the high-quality implementation of the comprehensive application and innovative practice levels, highly depends on a stable, in-depth, and institutionalized school-enterprise cooperative education mechanism. It is essential to promote the transformation of school-enterprise cooperation from a loose "acquaintance-based" collaboration to a deep "institutionalized" integration, achieving resource sharing, joint process management, collaborative talent cultivation, and shared responsibility.

The primary path is to establish a bidirectional interactive mechanism of an "Enterprise Mentor-in-Residence System" and "Teacher Enterprise Workstations." On the one hand, senior technical experts, project managers, and skilled craftsmen from enterprises are hired as fixed "Industry Mentors," who not only undertake some practical course teaching and guide graduation designs but also regularly reside on campus to participate in professional development seminars, practical project development, and technical lectures, directly injecting the technical standards, management culture, and latest trends of the industry frontline into the campus. On the other hand, a sound system should be established for full-time teachers to regularly practice at "Teacher Enterprise Workstations," requiring teachers to accumulate no less than six months of full-time enterprise practice every five years, deeply participating in real enterprise engineering projects or technology research and development, and transforming the practical results into teaching cases, practical training projects, or teaching reform topics. This bidirectional flow ensures that the "dual-teacher" quality of the school's teaching staff is constantly renewed, and the teaching content resonates with the pulse of the industry.

A deeper path lies in comprehensively upgrading the cooperative base from an "internship base" that provides visiting and internship opportunities to a "Joint Platform for Technological Breakthroughs and Talent Cultivation." Schools and cooperative enterprises jointly build a high-level industry-education integration practical training base or industry college integrating "practical teaching, technology research and development, social training, and skills appraisal." On this platform, the real production tasks and technical challenges of enterprises can be transformed into students' comprehensive practical training projects or graduation design topics; the school's laboratories and scientific research equipment can provide testing and experimental services for enterprises; and schools and enterprises can jointly apply for vertical scientific research projects or undertake horizontal technical service projects, with teachers and students participating together.

4.3 Evaluation System Building

To align with an innovative practice-based teaching system, it is essential to thoroughly reform traditional evaluation methods that primarily rely on written exams and emphasize rote memorization. Instead, a comprehensive evaluation system should be constructed, using the achievement of core professional competencies as the benchmark, emphasizing both process and results, and involving multiple stakeholders. The core logic of this system is: students will learn what is evaluated; students will learn how they are evaluated.

The evaluation content must shift from assessing theoretical knowledge to comprehensively examining the ability to solve complex engineering problems. This requires designing a series of authentic evaluation tasks that can reflect the ability dimensions of "technical implementation, site management, and technical optimization." Examples include: Process Simulation Operation and Troubleshooting: On a virtual simulation platform or physical training device, preset faults (such as abnormal measurement data or equipment operation failures) are set up, requiring students to complete standard operations and diagnose and solve problems, examining their standardized execution and adaptability. On-Site Situational Problem Solving: Provide a video of a construction site or a description of a complex technical case, requiring students to analyze the root cause of the problem, propose solutions, and demonstrate their rationality, examining their ability to connect theory with practice and make engineering decisions. These evaluation tasks highly simulate real-world job challenges, effectively guiding students' learning focus toward competency development.

In terms of evaluation methods, the organic combination of formative assessment and summative assessment must be strengthened. Formative assessment focuses on students' performance during the completion of practical projects, including the rationality of work plans, information retrieval and tool usage skills, teamwork and communication skills, the completeness of work logs, and the depth of reflection. This can be achieved through learning portfolios, observation records, peer evaluation, and other methods. Summative assessment focuses on the quality of the final project output, such as the standardization of design drawings, the accuracy of calculation sheets, the completeness of construction plans, the feasibility of model construction operations, and the innovativeness of research and development reports. The combination of the two can not only avoid the drawbacks of "one exam determines fate" but also guide students to pay attention to the accumulation and reflection of the learning process.

A more critical step is to actively introduce industry certifications and skill level certificates, and organically integrate "X Certificates" into the talent training and evaluation system. The "1+X" certificate system launched by the state provides an authoritative third-party competency evaluation standard for vocational undergraduate education. For construction engineering majors, the standards and requirements of vocational skill level certificates such as "Building Information Modeling (BIM)," "Prefabricated Building Component Production and Installation," "Construction Engineering Blueprint Reading," and "Digital Application of Engineering Cost" can be deeply integrated into the teaching content and assessment standards of relevant courses. Students can participate in the corresponding certificate examinations through course learning and centralized practical training. Obtaining vocational skill level certificates that are widely recognized by the industry is not only an authoritative endorsement of students' competency levels in specific fields, enhancing their employment competitiveness, but also an external verification of the quality of talent training in schools, forming a virtuous cycle of "integrating certificates with courses, promoting learning through certificates, and verifying teaching through certificates."

5. Conclusion

In the face of the profound changes in the construction industry and the higher demands placed on technically skilled personnel, vocational undergraduate education must break away from the path dependence of traditional disciplinary systems and construct a new paradigm for talent cultivation that is driven by real industry needs and centered on practical innovation capabilities. Taking the construction engineering major as an example, this study demonstrates the effectiveness of a systematic strategy, from precise goal positioning and modular curriculum restructuring to in-depth industry-education integration in practical teaching and evaluation reform. In the future, vocational undergraduate education should further strengthen the institutionalized construction of school-enterprise collaboration, dynamically respond to technological changes, and integrate industry standards, real-world projects, and technological research and development more deeply into the entire education process. This will achieve the organic connection of the education chain, talent chain, industrial chain, and innovation chain, and explore a sustainable path for cultivating a large number of high-level technically skilled personnel who can be competent in complex engineering tasks, promote technological innovation, and serve industrial upgrading.

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