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Research on the Construction of Modular Curriculum System for Architectural Engineering Major of Vocational Undergraduate Under the Background of Intelligent Construction

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Abstract: Against the backdrop of multiple industrial transformations including intelligent construction, urban renewal and conservation of historical and cultural heritage, profound changes have taken place in the competency requirements for positions in the construction industry. The industry is in urgent need of high-end skilled talents with solid theoretical foundations, practical engineering capabilities and innovative competence to solve complex engineering problems. As the undergraduate level of vocational education, vocational undergraduate education should neither simply copy the curriculum of civil engineering discipline in general undergraduate universities nor directly upgrade higher vocational college curricula. Based on the practical demands of the construction industry, this paper starts with an analysis of industrial background and talent demands, analyzes the principles for constructing the curriculum system. Taking the reform practice of Architectural Engineering Major in Zibo University of Vocational Technology as a case study, this paper constructs a modular curriculum system featuring "Solid Foundation + Specialized Skills + Innovative Competence". It elaborates on the composition, internal logic and implementation supporting conditions of curriculum modules, analyzes existing problems in practice and puts forward optimization paths, so as to provide references for curriculum construction of civil engineering-related majors at the vocational undergraduate level.

Keywords: Vocational Undergraduate; Architectural Engineering; Intelligent Construction; Modular Curriculum System; Talent Demand

1. Introduction

Opinions on Promoting the High-quality Development of Modern Vocational Education [2] clearly proposes to vigorously develop vocational undergraduate education and cultivate high-level technical and skilled talents. Vocational undergraduate education features both undergraduate academic level and the type attribute of vocational education, and the curriculum system serves as the core carrier for achieving talent training objectives. With the coordinated development of intelligent construction and new-type building industrialization advancing in China's construction industry, new business forms such as urban renewal, reinforcement of existing buildings and conservation of ancient buildings have emerged continuously. Positions in the construction industry are transforming from traditional construction operation to digital, intelligent and integrated directions. Civil engineering programs in general undergraduate universities lay emphasis on theoretical research yet lack sufficient practical engineering training; while architectural majors in higher vocational colleges strengthen practical training but have weak foundations in mathematics and mechanics, limiting their ability to tackle complex engineering problems. Neither type of talent supply can fully meet the practical needs of industrial transformation and upgrading.

The curriculum system directly determines students' knowledge structure, competency structure and literacy structure. Some civil engineering majors of vocational undergraduate suffer from ambiguous curriculum positioning, copying curricula from general undergraduate universities or higher vocational colleges, insufficient integration of new-technology content, imbalanced proportion of theory and practice, and shortage of innovative and expanding courses. Accordingly, based on investigations of industrial posts and following the teaching rules of vocational undergraduate education, this research constructs a modular

curriculum system through school-enterprise collaboration to realize the coordinated development of theoretical foundation, post competency and innovation capacity.

2. Industrial Development Background and Talent Demand Analysis for the Major

2.1 Industrial Development Background

The construction industry is currently undergoing multiple transformations. On one hand, intelligent construction is being widely promoted. Digital technologies such as BIM, smart construction sites, prefabricated buildings, construction robots and 3D laser scanning have been widely applied. The whole process of engineering design, construction and project management is undergoing digital transformation, and posts have significantly higher requirements for the application capability of digital tools. On the other hand, the urban renewal initiative is further deepened. A large number of existing buildings in China are entering the cycle of quality improvement and renovation, and businesses including identification, reinforcement and energy-saving renovation of existing buildings keep expanding. In addition, conservation of historical and cultural heritage has attracted high attention, making surveying, renovation and conservation of ancient buildings emerging business directions in the construction sector.

Industrial transformation brings iteration in post connotations. Traditional construction posts are no longer confined to the design and construction of new buildings, but extend to diversified scenarios such as renovation of existing buildings and conservation of historic buildings. The criteria for talent evaluation in the construction industry have shifted from "being able to read drawings and conduct construction" to compound talents capable of solving complex engineering problems, mastering digital tools, engaging in both new-building projects and existing-building renovation projects, and possessing technological innovation capabilities.

2.2 Industrial Posts and Talent Competency Demands

Through interviews and questionnaire surveys with multiple construction enterprises including Shandong Jincheng Construction Co., Ltd., the Architectural Engineering Major for vocational undergraduate mainly targets three post groups: structural engineers, technical engineers and project management engineers. The general competency demands for vocational undergraduate talents from the industry can be summarized into four points:

① Possess undergraduate-level theoretical foundations in mathematics and mechanics to analyze complex engineering working conditions;

② Be proficient in modern digital tools such as BIM and intelligent surveying to adapt to the transformation toward intelligent construction;

③ Have practical engineering capabilities to cope with various engineering scenarios including new-building construction, urban renewal and ancient-building renovation;

④ Possess innovative awareness and lifelong-learning ability to keep up with the iteration of new industrial technologies, as well as teamwork competence and engineering ethics literacy.

2.3 Practical Contradictions in Current Talent Training Curricula

Combined with college investigations, three prominent contradictions exist in the current curriculum system, calling for reconstruction of modular curricula based on post competencies.

Firstly, the contradiction between theoretical depth and post competency. Copying curriculum schemes of general undergraduate universities leads to overemphasis on theories and insufficient practice, resulting in students' inadequate ability to solve on-site engineering problems; simply upgrading higher vocational curricula, by contrast, brings weak theoretical foundations and fails to meet undergraduate-level requirements for solving complex engineering problems.

Secondly, the contradiction between traditional teaching content and new industrial business forms. Curricula focus more on new-building teaching, while content related to intelligent construction, urban renewal and ancient-building renovation is fragmented without systematic support of curriculum modules.

Thirdly, the contradiction between unitary curriculum mode and students' diversified development. Posts cover design, construction and management, together with expanding directions such as surveying, reinforcement and renovation. Uniform curricula can hardly satisfy students' differentiated development needs, and carriers for innovative practical teaching are

insufficient.

3. Logic for Curriculum System Construction

Guided by the talent training objective for compound and innovative high-end talents, starting from competency demands of the three post groups, this research follows the logic of "post competency decomposition to curriculum module division to curriculum setting to supporting practical chains to quality support guarantee", and constructs the modular curriculum system of "Solid Foundation + Specialized Skills + Innovative Competence".

Meanwhile, a four-level teaching chain consisting of basic projects, special projects, comprehensive projects and innovative projects is matched to break barriers between theoretical teaching and engineering practice. A supporting matrix of curricula against training specifications is established to clarify the supporting intensity of each course for training indicators, ensuring that talent training objectives are implementable and evaluable.

4. Framework of the Modular Curriculum System of "Solid Foundation, Specialized Skills and Innovative Competence"

4.1 Solid Foundation Module: Consolidate Underlying Capabilities for Sustainable Development

The solid foundation module is composed of public basic courses, mathematics-physics basic courses and major basic courses. It focuses on consolidating students' ideological and political literacy, scientific and cultural literacy, foundations in mathematics, mechanics and introductory major knowledge, serving as the cornerstone for subsequent major studies and long-term career development.

Public basic courses implement the fundamental task of fostering virtue through education. Ideological and political theory courses are offered, along with courses covering national security education, Introduction to the Community for the Chinese Nation, labor education, Introduction to Artificial Intelligence, Innovative Thinking and Project Practice. Elective public courses on humanities, social sciences, science and art are provided to shape students' ideals and beliefs, physical and mental quality, humanistic literacy and labor concepts.

Mathematics-physics basic courses include Advanced Mathematics, Linear Algebra, Probability and Mathematical Statistics, and University Physics. Different from higher vocational colleges that downplay mathematics and physics, this module strengthens mathematics and physics foundations to provide theoretical tools for mechanical calculation, structural modeling and engineering data analysis, satisfying undergraduate-level requirements for analyzing complex engineering problems.

Major basic courses include Architectural Drawing and CAD, Building Materials, Theoretical Mechanics, Mechanics of Materials, Building Architecture, Intelligent Surveying Technology, Structural Mechanics, Soil Mechanics and Foundation Engineering, and Fundamentals of Building Information Modeling. Introductory major training covering drawing reading, sketching, material cognition, mechanical analysis, surveying and mapping, and basic BIM skills is delivered to build a bridge from public basic courses to major core courses.

4.2 Specialized Skills Module: Focus on Core Vocational Competencies for Post Groups

Targeting the three post groups of structural engineers, technical engineers and project management engineers, the specialized skills module is divided into four curriculum groups: design-oriented, construction-oriented, information-technology-oriented and management-oriented. It realizes integration of posts, courses, competitions and certificates to cultivate students' core vocational competencies for posts.

Design-oriented courses include Building Structures and Building Seismic Resistance. Students are trained in component design, structural calculation and seismic checking to acquire capabilities for small-and-medium building structural design for structural engineer posts.

Construction-oriented courses include Building Construction Technology, High-rise Building Construction and Intelligent Construction Technology. Students master construction techniques of divisional and sub-divisional projects, prefabricated construction and application of intelligent equipment for on-site technical engineer posts.

Information-technology-oriented courses include Fundamentals of Building Information Modeling and Application of Building Information

Modeling. Students receive training in BIM modeling, collision detection, construction simulation, as well as collaborative management and control of progress-cost-quality to respond to the digital transformation of intelligent construction.

Management-oriented courses include Building Construction Organization, Architectural Engineering Project Management, Measurement and Valuation of Architectural Engineering, and Quality and Safety Management of Architectural Engineering. Competencies such as construction planning, cost compilation, quality-safety management and contract administration are cultivated to match requirements for project management engineer posts.

4.3 Innovative Competence Module: Expansion and Improvement for New Industrial Business Forms

As a feature of the vocational undergraduate curriculum system, the innovative competence module targets emerging businesses in the construction industry. Direction-specific selective courses and general elective courses are set to cultivate students' innovative thinking and adapt to diversified employment directions.

Combined with the iteration of talent training programs for cohorts of 2025 and 2026, this research upgrades the former UAV surveying & urban renewal direction into two directions: urban renewal, and conservation of ancient buildings, which align with national strategies. For the urban renewal direction, courses including Intelligent Building Detection Technology, Identification and Reinforcement of Building Structures are offered for posts engaged in detection, reinforcement and energy-saving renovation of old buildings. For the ancient-building conservation direction, courses including Safety Identification of Ancient-building Structures and Renovation & Conservation of Ancient Buildings are set for posts covering surveying of historic buildings, disease diagnosis and compilation of renovation schemes. Students select one of the two direction modules for study. Meanwhile, optional courses such as Intelligent Management of Engineering Projects, Intelligent Machinery and Robots, and Engineering Bidding and Contract Administration are provided to broaden students' knowledge scope.

4.4 Supporting Practical Teaching Chain

Independent practical courses are arranged in the system, including cognitive practice, social practice, on-the-job internship, graduation project (thesis), as well as centralized special training courses such as Building Construction Technology, Concrete Structure Design and Comprehensive Application of BIM Technology. Assessment requirements of advanced vocational skill-level certificates such as architectural engineering drawing reading and BIM are integrated into curriculum standards. Real enterprise drawings and project cases are adopted in teaching to realize in-depth integration of theory and practice.

5. Practical Dilemmas and Optimization Strategies of the Curriculum System

5.1 Main Dilemmas in Practice

(1) Insufficient supply of innovative projects. Innovative projects rely heavily on real technological-renovation and renovation projects from enterprises. Restricted by enterprises' production tasks, such projects are hardly open to teaching on a large scale. Some teaching activities can only adopt virtual simulation projects, and students have limited opportunities to deeply participate in enterprises' technological research and development.

(2) Uneven teaching capabilities of part-time enterprise teachers. Enterprise engineers possess abundant practical engineering experience yet vary in instructional design and classroom teaching capabilities. Restrained by their full-time jobs, they can only devote limited time to teaching, exerting impacts on the teaching quality of expanding-direction courses.

(3) Pressure of curriculum renewal brought by rapid iteration of industrial technologies. Technical standards for intelligent construction, urban renewal and ancient-building renovation keep updated, calling for dynamic iteration of curriculum cases and teaching resources, which imposes high requirements on curriculum construction and teachers' teaching and research work.

5.2 Optimization Strategies

(1) Expand the resource library of innovative teaching projects. On one hand, deepen industry-education integration and continuously transform enterprises' technological-renovation projects into teaching cases. On the other hand, develop virtual simulation projects to make up

for the shortage of real-world projects. Improve the credit recognition mechanism to realize credit replacement for college student innovation projects and skill competition achievements.

(2) Improve management and capacity building for part-time enterprise teachers. Provide pre-service teaching training for part-time teachers and offer curriculum standards and templates for project-oriented instructional design. Optimize course scheduling to adapt to the work rhythm of enterprise practitioners. Establish class observation, supervision and incentive mechanisms for excellent performance to enhance the teaching quality of enterprise teachers.

(3) Establish a dynamic curriculum iteration mechanism. Set up a curriculum construction committee composed of in-house teachers and enterprise experts. The committee assesses new industrial technologies and standards every year, updates loose-leaf teaching resources and engineering cases, and timely integrates new industrial requirements into curriculum standards.

6. Conclusion

The curriculum system construction for Architectural Engineering Major of vocational undergraduate must be based on real industrial talent demands instead of simply copying modes of general undergraduate universities or higher vocational colleges. The modular curriculum system featuring "Solid Foundation + Specialized Skills + Innovative Competence" takes post competency as its logical starting point. Supported by the four-level project-oriented teaching chain as well as guarantees for teaching staff, practical training and evaluation, it realizes integrated cultivation of knowledge, competencies and literacy. Curriculum system construction is a process of continuous iteration and improvement. In follow-up work, we shall further deepen industry-education integration, enrich resources for innovative practical teaching, optimize full-time and part-time teaching teams, continuously track data on graduates' career development, and polish curriculum content, so as to cultivate more compound and innovative high-end skilled talents for the construction industry and provide practical references for curriculum reform of similar civil engineering majors at the vocational undergraduate level nationwide.

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