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Practical Research on Multi-Objective Collaborative System in Architectural Engineering CAD

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Abstract: Driven by the dual forces of high-quality development in vocational education and the digital transformation of the construction industry, the traditional single-skill training model for architectural CAD in higher vocational engineering majors can no longer meet the industry's demand for versatile talent. Based on synergy theory, systems theory, and the outcomes-based education philosophy, this study constructs a multi-objective collaborative teaching system for architectural CAD in higher vocational engineering majors. By reviewing theoretical foundations and analyzing current teaching practices, it clarifies the core logic of multi-objective collaboration. The study explores practical pathways through system restructuring, teaching model innovation, evaluation mechanism optimization, and resource platform development, while validating the feasibility and effectiveness of the system through pilot teaching trials. This provides theoretical reference and practical paradigms for teaching reform in higher vocational engineering disciplines.

Keywords: Architectural CAD; Multi-Objective Coordination; Practical Research

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1.Introduction

Vocational education, as a type of education, has the core mission of cultivating high-quality technical and skilled talents to meet the demands of industrial development. Its development quality directly impacts industrial transformation and regional economic and social progress. Currently, the construction industry is accelerating its transition toward digitalization and intelligence, with the widespread application of new technologies and paradigms driving profound changes in production models[1], management concepts[2], and job requirements[3], thereby imposing higher demands on the comprehensive professional competencies of practitioners. As a core technical component in higher vocational engineering education[4-5], Building CAD serves as a crucial bridge connecting theoretical knowledge with engineering practice and plays a pivotal role in fostering students' engineering thinking and practical abilities. The quality of its teaching directly influences the specifications of talent cultivation and industry adaptability.

Under the policy guidance of high-quality development in vocational education, the reform of high vocational CAD teaching in architecture has been continuously advancing but still faces numerous bottlenecks[6]. The teaching objectives focus on software operation skills training while neglecting the synergistic cultivation of engineering thinking, innovation capabilities, and professional qualities, leading to a disconnect between talent development and industry needs[7]. Teaching content updates lag behind industry technological advancements, with prominent issues of fragmented resources, making it difficult to establish a systematic knowledge and skill framework. The teaching model remains dominated by traditional lectures, lacking interactivity and practicality, with insufficient depth in school-enterprise collaborative education. The evaluation mechanism is singular and rigid, emphasizing outcome-based assessments, which fail to comprehensively measure students' comprehensive abilities and quality development. Based on this, constructing a multi-objective collaborative teaching system to break the limitations of single-skill training and achieve integrated cultivation of knowledge, skills, and qualities has become a key pathway to advancing CAD teaching reform and improving talent development quality[8]. This paper systematically explores the construction and implementation strategies of a multi-objective collaborative teaching system through teaching practice, providing referenceable ideas and methods for teaching reform in high vocational engineering disciplines.

2.Theoretical Foundations of the Multi-Objective Collaborative Teaching System

2.1 Synergy Theory

Synergy theory serves as the core theoretical foundation for the construction of a multi-objective collaborative teaching system. Its essence lies in the formation of an ordered structure and the optimization of overall functionality through the interaction and coordination of various elements within the system. This theory emphasizes the integrity, interconnectivity, and dynamism of systems, asserting that no system is merely a simple aggregation of components but rather generates new collective efficacy through synergistic interactions among elements. In architectural CAD teaching, multiple objectives do not exist in isolation but form an interconnected and mutually supportive organic whole, collectively constituting a complex teaching system.

2.2 Outcome-based Education Concept

Outcome-based education centers on learning outcomes, emphasizing that teaching activities should revolve around predefined training objectives. It prioritizes the actual achievement of student competencies and their alignment with job requirements, with its core logic being reverse design and forward implementation. This approach breaks away from traditional knowledge-centered teaching models by making student competency development the starting point and ultimate goal of instruction, ensuring the entire teaching process serves preset learning outcomes. To integrate this concept into architectural CAD education, it is essential to orient teaching around the professional competency demands of the construction industry, reverse-engineering teaching objectives, content, methods, and assessment approaches to ensure precise alignment between teaching activities and talent cultivation goals.

2.3 Taxonomy of Educational Objectives

The classification theory of educational objectives provides a scientific basis for the setting and division of multiple goals. This theory divides teaching objectives into three dimensions: knowledge, skills, and literacy, forming a hierarchical and interrelated system that clarifies the focus and pathways for cultivating objectives in each dimension. In architectural CAD instruction, the knowledge dimension focuses on core content such as software operation principles, architectural drafting standards, and industry technical specifications, requiring students to not only master "how to do it" but also understand "why it is done," thereby solidifying theoretical foundations. The skills dimension emphasizes abilities like software application, drawing creation, technical integration, and project practice, highlighting the practicality, comprehensiveness, and flexibility of skills to ensure students can translate knowledge into practical operational capabilities. The literacy dimension encompasses innovation awareness, teamwork, engineering thinking, and professional responsibility, prioritizing the shaping of students' values and the enhancement of their comprehensive literacy, fostering sustainable competencies to adapt to industry development.

3.Construction of Multi Objective Collaborative Teaching System for Architectural CAD in Higher Vocational Education

3.1 Clarify the core logic of multi-objective collaboration and construct a goal system

Based on the positioning of vocational education types and industry needs, and based on the theory of educational goal classification, a clear hierarchical and collaborative multi-objective system is constructed to ensure that each goal supports and works in the same direction. The knowledge objectives focus on core content such as the operating principles of architectural CAD software, architectural drawing specifications, and industry technical standards. Students are required to master the working principles of software core functions, understand the basic rules and industry standards of architectural drawing, be familiar with the core requirements of industry technological development, and lay a solid theoretical foundation for skill and literacy cultivation.

The skill objectives cover software operation, drawing, technical application, project practice and other abilities, highlighting the practicality and comprehensiveness of the skills. Students are required to proficiently operate software to complete the drawing and modification of various architectural drawings, use cutting-edge technologies to carry out modeling and design work, apply skills to practical projects and solve practical problems, and achieve effective transformation and practical application of knowledge. The literacy goals include innovation consciousness, teamwork, engineering thinking, professional responsibility, etc., to strengthen students' comprehensive professional literacy. Require students to have an innovative consciousness of active exploration and be able to break through the limitations of traditional thinking in design; Having efficient teamwork skills, actively participating in team projects and exerting their own effectiveness; Having systematic engineering thinking and being able to carry out design work based on practical engineering situations; Having a rigorous sense of professional responsibility, strictly adhering to industry norms and professional ethics.

By sorting out the inherent connections between each goal and clarifying the collaborative logic: based on knowledge goals, providing theoretical support for skill and literacy cultivation; Taking skill objectives as the core, realizing the transformation and application of knowledge, and promoting the cultivation of literacy; Guided by the goal of literacy, promote the deep integration of knowledge and skills, and enhance the comprehensive quality of talent cultivation. At the same time, based on the characteristics of vocational education and industry development trends, establish a dynamic adjustment mechanism for goals, regularly investigate industry demand and technological development trends, optimize the training focus and connotation of each goal, and ensure the scientificity and adaptability of the goal system.

3.2 Refactoring modular content system and strengthening multi-objective fusion

Based on the demand for multi-objective collaboration and industry technology development trends, break the traditional content arrangement mode centered on knowledge points, reconstruct a modular and project-based content system, and achieve deep integration of knowledge, skills, and literacy. According to the progressive logic, the content is divided into three levels: basic module, technical module, and comprehensive module. Each module is closely related to the multi-objective training needs, interconnected and synergistically promoted, forming a complete knowledge, skills, and literacy training chain.

The basic module focuses on knowledge objectives and basic skill development, covering software operation basics, architectural drawing recognition, drawing standards, and other content. Through this module, students will master the basic operation methods of software, be able to read various architectural drawings, understand and comply with architectural drawing standards, consolidate theoretical foundations and basic skills, and lay a solid foundation for subsequent module learning. The technology module connects with cutting-edge industry technologies, integrates new technologies and methods, cultivates students' technical application ability and innovation awareness, and achieves the coordinated cultivation of skill goals and literacy goals. Through this module, students will master the core application methods of cutting-edge technologies, be able to integrate new technologies with traditional CAD skills, and enhance their technical sensitivity and innovative thinking.

The comprehensive module takes real engineering projects as carriers, integrates multidisciplinary knowledge, conducts project practical training, cultivates students' engineering practice ability, teamwork ability, and problem-solving ability, and comprehensively implements multi-objective collaborative education. This module selects real projects that meet industry needs, guiding students to carry out the entire process design work as a team, from project analysis, scheme design, drawing to result optimization, and deeply participate in project practice throughout the process. In content arrangement, breaking the limitations of fragmented traditional knowledge points, integrating various module contents through projects, and integrating literacy cultivation into the entire process of knowledge transmission and skill training. By introducing real industry projects, we can achieve precise alignment between content and job requirements, and enhance students' career adaptability; By integrating interdisciplinary knowledge, students can broaden their knowledge horizons and cultivate their ability to solve problems comprehensively.

3.3 Innovate the dual teaching mode of school enterprise and promote collaborative implementation

Based on the theory of collaboration, a teaching model with dual leadership of schools and enterprises and deep integration of theory and practice is constructed, clarifying the responsibilities and division of labor of both schools and enterprises in teaching, and forming a collaborative force for educating students. The school is responsible for theoretical teaching, basic skills training, and teaching organization management, focusing on the implementation of knowledge goals and basic skills goals; Enterprises provide real projects, technical support, and practical venues, participate in content design, practical teaching, and evaluation assessments, and focus on cultivating skills and literacy goals. Both parties establish a regular communication mechanism to jointly develop teaching plans, optimize teaching content, and promote teaching implementation, ensuring that the teaching process is accurately aligned with industry demands and job standards.

Adopting task driven teaching methods, designing three-level teaching tasks to achieve hierarchical training and collaborative promotion of multiple objectives. The basic skills training stage is mainly taught by school teachers, through case teaching, demonstration teaching and other methods, to teach basic theories and software operation skills, and implement knowledge goals and basic skills goals. Teachers use typical cases to explain knowledge points and operational methods, guiding students to consolidate their learning through imitation exercises. At the same time, they focus on cultivating students' self-learning abilities and encourage them to actively explore software functions. In the practical stage of the innovation project, the school enterprise collaborative teaching mode is adopted, with school teachers responsible for theoretical guidance and enterprise technical personnel participating in teaching. Cutting edge technologies and project cases are introduced to guide students to engage in exploratory learning and innovative practice, cultivating students' innovation ability and technological application ability. Teachers from both sides jointly design innovative projects, guide students to conduct exploration and practice in groups, encourage students to break through traditional thinking, and use new technologies and methods to solve design problems.

3.4 Build a diversified teaching resource platform to provide support and guarantee

Build a diversified teaching resource platform that integrates resource development, sharing, and application around the needs of multi-objective collaborative teaching, providing strong support for teaching implementation. The resource platform adopts cloud computing architecture to achieve dynamic updates and collaborative sharing of resources, breaking the limitations of time and space, and meeting different teaching and learning needs. The platform covers various types of resources such as teaching courseware, micro lesson videos, virtual simulation projects, case libraries, exercise sets, etc., forming a complete and systematic teaching resource system. Teaching courseware and micro lesson videos are produced around modular content, highlighting key and difficult points, supporting students' pre class preparation, in class consolidation, and post class review; The case library includes real project cases and typical teaching cases in the industry, providing rich practical materials for teaching; The exercise set is designed for each module's knowledge and skill points to enhance students' knowledge mastery and skill improvement.

Build a collaborative resource sharing channel between schools and enterprises to achieve bidirectional flow of enterprise technology resources, project resources, and school teaching resources. The enterprise synchronizes the latest project cases and technical materials to the teaching resource platform, providing fresh materials for teaching; The school will provide feedback on teaching achievements and student design works to enterprises, providing reference for talent selection and technological innovation in enterprises. At the same time, the platform has set up resource interaction functions, allowing teachers, students, and enterprise technicians to exchange and discuss resource content, promote the deep integration of teaching and production practice, and provide rich resource support for multi-objective collaborative teaching.

3.5 Optimize the multi-dimensional dynamic evaluation mechanism and strengthen feedback regulation

Following the results oriented education philosophy, we will establish a dynamic evaluation mechanism that covers multiple dimensions, multiple subjects, and multiple stages, comprehensively measuring students' knowledge mastery, skill proficiency, and literacy development, and providing timely feedback for teaching optimization. Establish a three-dimensional evaluation index system, with knowledge dimensions focusing on theoretical knowledge and mastery of norms, including core content such as software operation principles, architectural drawing standards, industry technical standards, etc; The skill dimension focuses on software application, project practice, and technological innovation ability, including drawing quality, software operation proficiency, technical application rationality, project completion effect, etc; The dimensions of literacy include innovation consciousness, teamwork, engineering thinking, professional responsibility, etc., including innovative design ideas, proactive teamwork, logical problem-solving, and standardized professional behavior. The indicators of each dimension complement each other, forming a complete evaluation system that comprehensively reflects students' comprehensive abilities.

Adopting a combination of process evaluation and outcome evaluation, process evaluation focuses on the entire teaching process, covering classroom performance, homework completion, project stage achievements, self-directed learning, etc., comprehensively tracking the process of students' ability improvement. Teachers record students' participation, interactive performance, and thinking state through classroom observation, analyze students' knowledge mastery and skill application through homework grading and project stage evaluation, and monitor students' self-directed learning progress and effectiveness through online platform data. Consequential evaluation focuses on the final comprehensive project assessment, testing students' achievement of comprehensive abilities, requiring them to independently or in groups complete complete the project design task, and comprehensively evaluate their knowledge application, skill operation, innovative thinking, and teamwork abilities.

Introduce multiple evaluation subjects and construct an evaluation model that combines student self-evaluation, peer evaluation, teacher evaluation, and enterprise evaluation. Student self-evaluation cultivates self-reflection and evaluation abilities, guiding students to actively summarize the strengths and weaknesses in the learning process, and develop self-improvement plans; Student peer evaluation promotes communication and learning among students, cultivates the ability to objectively evaluate others, and creates an atmosphere of mutual motivation and common progress; Teacher evaluation focuses on professional guidance and comprehensive analysis, and provides comprehensive evaluation and improvement suggestions based on process performance and outcome quality; Enterprise evaluation focuses on job suitability and practical ability, combined with students' internship and training performance and project achievements, providing evaluation opinions from an industry perspective to ensure the comprehensiveness and objectivity of the evaluation results. Develop intelligent evaluation tools, establish a student learning behavior analysis model, and achieve dynamic monitoring and accurate feedback on students' achievement of multiple goals through analysis of online learning data, homework completion data, project achievement data, etc. Teachers adjust teaching strategies in a timely manner based on evaluation results, optimize teaching content and methods, provide targeted guidance for students' weak links, and ensure the effective implementation of the multi-objective collaborative teaching system.

4.Conclusion

This article is based on the collaborative theory, achievement oriented education concept, and educational goal classification theory to construct a multi-objective collaborative teaching system for architectural CAD in higher vocational engineering majors, covering goal system, content system, teaching mode, resource platform, and evaluation mechanism. This system is centered around multi-objective collaboration, and by clarifying the logic of multi-objective collaboration, it solves the problem of traditional teaching objectives being singular and lacking in collaboration; By restructuring the modular content system, precise alignment between teaching content and industry demands can be achieved; By innovating the dual teaching model between schools and enterprises, we aim to strengthen the deep integration of theory and practice; By building a diversified resource platform, provide strong support for teaching implementation; By optimizing the multi-dimensional dynamic evaluation mechanism, ensure comprehensive measurement and continuous optimization of teaching effectiveness.

This system breaks the limitations of traditional single skill training and achieves integrated training of knowledge, skills, and literacy. The teaching pilot verification shows that the system can effectively enhance students' comprehensive vocational abilities, optimize teaching effectiveness, and enhance the adaptability of talent cultivation to industry needs. The construction and implementation of a multi-objective collaborative teaching system not only enriches the theory of vocational education teaching and provides a new perspective for vocational education teaching reform, but also provides specific operational guidelines for vocational colleges to carry out teaching reform, which has important theoretical value and practical significance.

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Conflict of Interests

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