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TEACHING REFORM PRACTICE AND REFLECTION BASED ON POST-COMPETITION INTEGRATION AND VIRTUAL-REAL LINKAGE: A CASE STUDY OF THE COURSE "CONSTRUCTION ENGINEERING COST"

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Abstract: The digital transformation of the construction industry and the reform towards market-oriented pricing have raised new requirements for the cultivation of engineering cost professionals, and the traditional teaching model that stresses theory over practice can no longer match the demands of real positions. Taking the course Construction Engineering Cost as the research object, this paper builds a teaching model featuring post-competition integration, virtual-real linkage and ideological-political penetration, grounded in the integrated education concept of post, course, competition and certificate. Using real engineering projects as the carrier, the course content system is restructured according to the actual workflow of engineering cost management, and a three-stage, six-step instructional design of pre-class guiding, in-class introducing, exploring, doing and evaluating, and after-class extending is implemented, combined with virtual simulation technology and school-enterprise collaborative training bases, together with differentiated evaluation and value-added evaluation. Practice shows that the model effectively bridges the competence gap between classroom teaching and professional practice, and that students' job adaptability and comprehensive practical skills are markedly enhanced. Two bottlenecks remain to be addressed in the next stage, namely the in-depth development of case resources and the simulation coverage of authentic enterprise scenarios.
Keywords: Construction engineering cost; Post-competition integration; Virtual-real linkage; Teaching reform

1 INTRODUCTION

Project cost estimation is the core support for the standardized operation in the field of engineering construction and is directly related to the economic benefits and management quality of the project. The release and implementation of the 2024 version of the "Bill of Quantities Pricing Standard for Construction Projects" (GB/T 50500-2024) marks a new stage of market-oriented, refined and process-oriented management in the field of project cost in China [1]. This transformation places higher demands on the capability structure of practitioners - not only should they be able to "calculate quantities and set prices", but also "understand regulations, be capable of editing and reviewing, be able to organize and be good at negotiation", and be able to complete the entire process of cost control in complex engineering environments.

However, the reality is not so optimistic. Ultimately, the inertia of the traditional teaching model is still too great. For a long time, courses related to engineering cost have mainly been taught by teachers, with teaching content centered around quotas and lists. Students passively accept knowledge and lack systematic experience of the real working process [2]. Many teachers are also confused. Even though they have covered a lot of cases in class, students still have no idea where to start when it comes to their internship positions. The root cause of the problem lies in the "gap" between the teaching scene and the working scene. In the classroom, simplified cases and idealized data are used, while enterprises are confronted with complex blueprints, ambiguous information and multi-party games. There is a "last mile" or even "the last few kilometers" gap between the knowledge students acquire at school and the actual demands of their jobs.

In recent years, the integration of "positions, courses, competitions and certificates" has attracted widespread attention as an important path for vocational education reform [3]. Wang Wenli systematically explored the comprehensive teaching reform path of courses under the integrated education model of "positions, courses, competitions and certificates" [4]. Fan Guohui et al. proposed an implementation path from the perspective of digital transformation to achieve in-depth collaboration among positions, courses, competitions, and certificates through digital skills as a link [5]. Hu Qing et al. constructed the "OBE-CDIO" advanced teaching model and intelligent evaluation system, verifying the enabling effect of digital reform on vocational education [6]; Feng Gairong et al. explored the practical path for cultivating talents in the engineering cost major from the perspective of industry-education integration-driven development, emphasizing the crucial role of school-enterprise collaborative education in enhancing the quality of talent cultivation [7]. Yu Liting focuses on the cultivation of innovative talents in the engineering cost major under the background of digitalization and has proposed a systematic strategy of curriculum reconstruction, integration of digital technology and integration of industry, academia and research [8]. Tao Weiwei explored the teaching reform of the

engineering cost major in higher vocational colleges under the 2024 version list model and constructed a teaching innovation system of "three alignments, four integrations, and five modernizations" [9].

The above-mentioned research has reached a consensus at the conceptual level, but the operational plan provided for "how to truly integrate job positions, courses, competitions and certificates into the classroom teaching of a single course" is still not specific enough. Everyone has the idea, but when it comes to a class, a task, or an evaluation, how can it be done effectively? More empirical exploration is still needed. Based on this, this paper, relying on the "Construction Engineering Cost" course and taking real engineering projects as the teaching carrier, systematically implements the teaching reform of "integration of positions and competitions, interaction between virtual and real, and integration of ideological and political education", attempting to answer the following three questions: How to reconstruct the course content in accordance with the job process and competition standards? How can we achieve an effective connection between theory and practice within a limited number of class hours? How can the growth of students' abilities be truly reflected through diverse evaluations?

2 OVERALL DESIGN OF COURSE TEACHING

2.1 Course Positioning and Goal Setting

"Construction Engineering Cost" is a core course for the construction engineering and engineering cost majors, playing a crucial role in bridging theoretical teaching with on-the-job practice. Before the course was launched, the teaching team conducted in-depth research on core positions such as cost estimators and bidding specialists. Based on the standards of the National Vocational Skills Competition's engineering management event and the assessment requirements of the Certificate of Digital Application in Engineering Cost Estimation, the course objectives were set from three dimensions.

Knowledge Objectives: Master the composition and calculation procedures of construction and installation project costs, be familiar with the bill of quantities pricing norms and quota calculation rules, understand the preparation methods of tender control prices and tender offers, and be aware of the processing procedures for project settlement and final accounts.

Competency Objectives: Be capable of preparing tender documents and bid documents, be able to use cost software to prepare bill of quantities and formulate bid quotation strategies, be able to simulate bid opening and evaluation operations and prepare bid evaluation reports, and be able to identify contract risks and handle change claims.

Quality Objectives: Establish professional ethics of "openness, fairness, impartiality, honesty and trustworthiness", cultivate a meticulous and rigorous craftsmanship spirit, and enhance teamwork and communication skills.

It should be noted that these three dimensions are not linearly arranged in the order of knowledge first, then ability, and finally ideological and political education. Instead, they are nested within each other and exert efforts simultaneously. For instance, when students are preparing tender documents, they should not only apply legal knowledge, but also practice operational skills and demonstrate the professional quality of honest quotation. A good class should be a "three-dimensional resonance" rather than a fragmented three-part structure.

2.2 Student Situation Analysis and Teaching Strategies

The target audience for this course is 39 third-year students majoring in civil engineering. At the beginning of the course, a comprehensive assessment of students' learning conditions was conducted through the Learning Pass platform, questionnaires and pre-course tests.

Data shows that 85% of students have a preliminary understanding of the basic process of compiling cost documents in bidding and tendering documents, but only 32% can accurately distinguish the bidding requirements of different types of projects, 28% are familiar with the skills of compiling bidding documents, and 25% can complete the review of bidding documents in a standardized manner. In other words, students know about this, but they still don't know where to start when it comes to doing it. The core shortcomings are concentrated in three aspects: the bidding quotation strategy, the calculation of project fees for measures, and the operation of BIM electronic bidding and tendering - these are precisely the key points of the skills competition and the assessment of vocational skills level certificates. In terms of learning preferences, 78% prefer practical operation, 82% tend to collaborative learning, and 98% are accustomed to online self-study. However, their systematic analysis ability for complex normative documents is generally weak, and about 60% are unable to quickly sort out the core contradictions when facing actual cases.

Based on this, the teaching team has determined the core strategy of "integrating positions and competitions, and linking virtual and real activities". "Integration of job and competition" enables teaching content to directly align with job processes and competition standards. Every piece of content that students learn can be found in the corresponding scenarios of the competition's real questions. This way, they not only practice their job skills but also prepare for the competition at the same time. The "virtual-real interaction" involves completing process simulation in a virtual simulation training center and then experiencing the real environment at an off-campus enterprise base. The two alternate and reinforce each other.

2.3 Reconstruction of Course Content

Traditional textbooks are arranged in the logic of "theory - method - case", and after students finish learning, they often only see the trees but not the forest. This article selects the chapter "Preparation of Bidding and Tendering Cost Documents", and reconstructs the content into four teaching tasks (a total of 8 class hours) based on the workflow of real projects, covering four major sections: bidding planning and document preparation, bidding decision-making and document preparation, bid opening, evaluation and awarding, and contract management and claims. Each task is set with clear ability goals and evaluation criteria to ensure that students can be immediately put into use in their corresponding positions after completing each task. Clear "trade-offs" have been made in the content. The quota pricing of engineering cost takes up a considerable amount of space in traditional textbooks. However, the list pricing has become the mainstream model. Therefore, the quota content has been significantly reduced, and the freed-up class hours have been allocated to high-frequency work contents such as electronic bidding and tendering operations, BIM quantity calculation applications, and claim practice. This kind of "discarding the old and adding the new" ultimately means keeping teaching in line with the pace of the industry, rather than having students learn a bunch of outdated things.

3 TEACHING IMPLEMENTATION PROCESS

3.1 Design of the "Three Stages and Six Steps" Teaching Process

The overall teaching process is designed in three stages: "pre-class introduction - in-class internalization - post-class expansion". During the class, it is further divided into four links: "introducing - exploring - doing - evaluating", forming a six-step teaching chain of "guiding - introducing - exploring - doing - evaluating - extending". The core idea is to have students enter the classroom with questions before class, drive hands-on operations with real tasks during class, and consolidate and transfer through extended tasks after class.

Take the task of "preparing tender documents" as an example. The "guiding" stage before class: Teachers release preview task packages (regulatory documents, case videos, operation guides) through Learning Pass. Students complete the pre-class assessment, and teachers adjust the teaching focus based on the data - this is "teaching based on learning", using data rather than experience to identify key and difficult points.

In class, "introducing scenarios": The teacher starts with a real case of a bidding dispute and guides students to analyze the key points of the dispute. The introduction of cases makes students realize that the provisions of laws and regulations "are not just empty talk on paper; if problems arise, they will have to bear legal consequences", naturally integrating the ideological and political elements of integrity [10], and at the same time stimulating their interest in exploration.

In class, "Exploring New Knowledge": The teacher elaborately explains the core terms and compilation techniques of tender documents, and analyzes the key and difficult points in combination with competition standards and certificate examination points. "Intensive teaching" is not a full-class lecture. Instead, it focuses on the common problems exposed in the pre-class assessment and the key concepts that students cannot understand, and intersperses questions and discussions at any time to maintain classroom interaction.

In class, "task completion": Students are divided into groups to use cost estimation software and electronic bidding simulation systems to prepare bidding documents based on real project data. Thirty-nine people were divided into seven groups, each simulating a bidding unit. Members respectively took on roles such as project manager, cost estimator, and data clerk, while teachers and enterprise mentors provided on-site guidance. In the process of "doing", students truly transform the legal knowledge and compilation skills they have learned before into operational abilities.

In class, "evaluation of achievements": Each group presents their achievements and explains their ideas. Teachers, enterprise mentors, and other groups provide joint comments. Comments are not simply about giving scores; rather, they involve sorting out common problems for the whole class to analyze. For instance, if a certain group makes a systematic mistake in the calculation of measure project fees, taking this opportunity to analyze the root cause of the mistake together with the whole class is much more memorable than directly giving the correct answer.

After class, "Expand application": Students revise and improve the documents and submit them. The teacher assigns an extension task - comparing and analyzing the differences among various types of bidding documents, or observing the real bidding process at the school-enterprise cooperation base to achieve knowledge transfer.

3.2 Construction of "Virtual-Real Interaction" Scenarios

The teaching venues are orderly switched among multimedia classrooms, virtual simulation training centers, on-campus simulation training rooms and enterprise practice bases. The virtual simulation center undertakes the function of "refining the process" - simulating the entire process from announcement issuance to bid opening and awarding. Students can operate repeatedly without fear of making mistakes, and the system automatically records the operation steps for teachers to analyze weak links. However, simulation does have its limitations. The data is preset and will not encounter unexpected situations, nor is it as complex as interpersonal communication. Therefore, the enterprise base undertakes the function of "verifying true knowledge", where students observe bidding and tendering meetings in real projects, participate in the preparation of cost documents, and experience the real work pace and pressure. The "virtual and real interaction" provides students with both a safe space for trial and error and a real experience, making the teaching effect much better than that of a single scenario.

The teaching team has also developed a series of digital resources to complement the "virtual-real interaction", including BIM model display, micro-lessons on cost calculation, typical case libraries, ideological and political micro-lessons, etc. These resources serve as pre-class preview materials, in-class auxiliary tools, and post-class review materials. Students have given feedback saying, "In the past, we just listened to the teacher in class. Now, we can take out the video and watch it again at any time without worrying about falling behind."

3.3 Organic Integration of Ideological and Political Elements

The field of engineering cost estimation places particular emphasis on professional integrity, regulatory compliance, and fair practice. This course incorporates the principles of integrity, lawfulness, fairness, impartiality, contractual responsibility, and professional craftsmanship throughout the teaching process. Rather than adopting a rigid or superficial approach to ideological and professional education, the course integrates these principles naturally with relevant teaching content. For example, when teaching the preparation of tender documents, practical cases concerning compliance requirements, professional standards, and the importance of maintaining accurate and reliable documentation are introduced to help students develop a strong awareness of professional responsibility and standardized practice. When simulating the bid evaluation, set up a "benefit temptation" scenario - if a certain bidder is your relative, how would you evaluate? Through role-playing, let students experience the weight of "fairness and impartiality". The contract management stage guides the understanding of the spirit of the contract through the discussion of claim cases. After class, students gave feedback saying, "I used to think legal provisions were dull. But through case analysis, I found that there were painful lessons behind each regulation." This indicates that the ideological and political approach of "case-driven + role experience" is much more effective than traditional preaching.

4 TEACHING EFFECTIVENESS AND EVALUATION ANALYSIS

4.1 Design of the Evaluation System

This course has established an evaluation system that is "all-round, involving all personnel and covering the entire process". "Comprehensively" covers the three dimensions of knowledge, ability and quality; "All staff" includes teachers, enterprise mentors, and self-assessment and mutual assessment by students. The "whole process" runs through pre-class assessment, in-class observation and post-class tasks.

A special "value-added assessment" is introduced, focusing not on students' "final achievement level," but rather on "how much they have improved from their starting point." Specifically, at the beginning of the course, each student undergoes a baseline assessment of core competencies, and another assessment is conducted at the end. The growth is quantified by comparing results before and after, with evaluation dimensions including teamwork, case analysis, practical skills, and sense of responsibility. This approach is particularly motivating for students with weaker foundations—they may not achieve the highest final grades, but if they show the greatest improvement, they still receive recognition. Additionally, awards in skill competitions and certifications in vocational skills can be converted into course credits, further stimulating intrinsic motivation to learn.

4.2 Effect Analysis

In terms of learning status, the completion rate of online tasks has risen from 70% before the reform to over 95%, and the participation rate in classroom discussions is close to 100%. Students have reported that "there is always something to do in every class, not just listening." Project-based teaching and real cases are the key factors in stimulating interest. The learning state has shifted from passive "I have to learn" to active "I want to learn".

In terms of practical ability, the pass rate of students in the core difficulty of "Bidding Quotation Preparation Strategy" has increased from 25% to 78%, and the pass rate of "BIM Electronic Bidding and Tendering Operation" has risen from less than 20% to 85%. After the "do - evaluate - improve" cycle training, most groups were able to independently complete the entire document compilation and simulation operations in the later stage.

In terms of professional ethics, at the beginning of the course, the mentality of "good enough" was quite common among some students when compiling documents, and the formats were not standardized and the data was not rigorous. After multiple rounds of "evaluation-correction" cycles and guidance from enterprise mentors, the standardization of the documents has significantly improved in the later stage. In the simulated bid evaluation, students can consciously avoid "personal connections", and in the preparation of quotations, they can adhere to "quotations based on facts" - the awareness of integrity is gradually being internalized as a behavioral habit. Of course, it should also be objectively said that reforms in one semester cannot solve all problems. The comprehensive improvement of capabilities is a long-term process. Curriculum reform is only the first step, and it still needs to be continuously tested and optimized in more teaching cycles.

5 REFLECTION AND IMPROVEMENT

5.1 Characteristics and Innovation

There are three points worth summarizing in this reform. The first is the "reverse design" approach - starting from the job process and competition standards to "work backward" the course content, ensuring that teaching is closely aligned with industry demands, rather than "working backward" from the textbook. The second is the "virtual-real interaction" design - the simulation system solves the problem of "refining processes", while enterprise training solves the problem of "verifying true knowledge", forming a progressive training path from simulation to reality. The third is the "case-driven" ideological and political strategy - naturally permeating professional spirit through real cases and role experiences, and the acceptance rate among students is significantly higher than that of traditional preaching.

5.2 Shortcomings and Improvement Directions

First, the depth of case resources is insufficient. Currently, the focus is mainly on small and medium-sized projects, lacking complex scenario cases such as large-scale EPC general contracting and PPP projects. Students' industry perspectives need to be broadened. The improvement direction is to deepen the cooperation between schools and enterprises, establish a dynamic case library update mechanism, and regularly introduce cutting-edge materials. Second, the coverage of simulation resources is limited, and simulations for complex links such as contract change negotiations and claim mediation are relatively scarce. It is planned to jointly develop a virtual simulation teaching module covering the entire process of cost management with software enterprises. Thirdly, the refinement of value-added evaluation is insufficient. Currently, it mainly relies on simple comparisons of pre- and post-assessments and teachers' subjective observations, lacking scientific quantitative tools and long-term tracking mechanisms. We will collaborate with educational measurement experts to develop a more scientific value-added evaluation scale for professional core competencies and establish electronic personal growth files for students.

6 CONCLUSION

The core of the teaching reform of the "Construction Engineering Cost" course is to respond to the question of "how to cultivate 'ready to fight' construction engineering cost talents". The practical exploration in this article indicates that the teaching model of "integrating job positions and competitions, linking virtual and real elements, and integrating ideological and political education" is an effective path choice. By reconstructing course content with real projects as the carrier, building teaching scenarios with virtual simulation and enterprise training as the support, and stimulating learning motivation with "three-all" evaluation and value-added evaluation as the orientation, it is possible to effectively bridge the "gap" between teaching and work, and achieve a paradigm shift from passive acceptance to active reconstruction.

However, it is also necessary to clearly recognize that teaching reform is never something that can be achieved overnight. One semester of practice is just the beginning. There is still a lot of work to be done in the subsequent aspects such as the continuous construction of digital teaching resources, the improvement of the in-depth cooperation mechanism between schools and enterprises, and the scientific evaluation system. Especially with the accelerated advancement of digital transformation in the construction industry, course teaching also needs to maintain dynamic iteration, promptly integrating new technologies, new standards, and new norms into teaching content and processes. It is hoped that the practical experience and reflection in this article can provide some referenceable ideas for the teaching reform of similar courses. We also look forward to more colleagues participating in this reform practice to jointly promote the improvement of the quality of engineering cost talent cultivation.

COMPETING INTERESTS

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