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EXPLORATION OF THE PRACTICAL TEACHING SYSTEM FOR THE CONSTRUCTION COST ENGINEERING MAJOR IN PRIVATE HIGHER EDUCATION INSTITUTIONS

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ABSTRACT

Against the backdrop of rapid advancements in digital architectural technologies, private universities' construction cost engineering programs face numerous challenges in practical teaching. For instance, the practical teaching system lacks holistic planning and coordination across its components; practical courses suffer from poor continuity and significant content redundancy; and practical teaching resources are severely limited. In response to these issues, Hubei University of Commerce has undertaken reforms aimed at strengthening students' engineering practice skills and innovative thinking. Specifically, it has restructured the practical teaching framework, establishing a tiered, graduated system tailored to the construction cost engineering major; redesigned the knowledge map and optimized practical content to address fragmentation and duplication; and, with industry–education integration at its core, developed a comprehensive resource system, established off-campus training bases, incorporated cutting-edge technologies, upgraded on-campus facilities, formed dual-faculty–enterprise practical teaching teams, and promoted deep collaboration between the university and industry. These reforms have yielded marked improvements in teaching outcomes, enhancing the development of engineering competence and fostering a stronger sense of innovation among emerging engineering professionals.

Keywords: Practice System, New Engineering, Construction Cost Engineering, Industry–Education Integration

1 INTRODUCTION

New engineering education emphasizes the integration of theory and practice, focusing on cultivating students' engineering skills, innovative spirit, and interdisciplinary competencies [1-3]. With the rapid advancement of digital construction technologies, the construction industry's demand for talent has undergone profound changes, posing numerous challenges to practical teaching in the field of construction cost management. On one hand, inadequate planning of the practical teaching system results in fragmented hands-on activities that lack coherence and synergy, thereby hindering the development of students' comprehensive capabilities [4-8]. On the other hand, poor continuity among practical courses and redundant content lead to the inefficient use of valuable educational resources,

undermining the effectiveness of practical instruction [9]. Furthermore, a shortage of practical teaching resources—particularly advanced technologies and innovative learning environments—limits students' ability to tackle complex engineering problems [10-11]. In addition, private institutions face difficulties in establishing stable off-campus internship bases and recruiting experienced faculty, further constraining efforts to improve the quality of practical education [12-14]. In response to the aforementioned issues, the Construction Cost Engineering program at Hubei University of Commerce has taken proactive measures, guided by ABET's "Engineering Accreditation" standards, and undertaken a comprehensive reform of its practical teaching. (1) A tiered practical teaching system—comprising "basic practice, professional practice, and engineering practice"—has been established, transforming practical courses from a horizontal adjunct to theoretical courses into an independent, vertically structured framework, thereby fostering systematic interconnections among courses [15-18]. Independent yet coherent specialized laboratory modules have been introduced, creating a multidimensional course network that strengthens the vertical integration and continuity of professional-practice courses. Emphasis is placed on cultivating engineering competencies and innovation, promoting deep industry-education collaboration, ensuring thorough integration and seamless connectivity among laboratory courses, and efficiently facilitating the linking and synthesis of knowledge. (2) By mapping out a knowledge graph, the content of practical instruction has been optimized: with competency requirements as the guiding objective and full coverage of knowledge points as the constraint, the practical curriculum has been restructured based on this knowledge-graph-driven approach [19]. This addresses issues such as disjointed or redundant practical content and suboptimal learning outcomes, while also resolving challenges related to compressing instructional hours and integrating knowledge points effectively. Course components have been reorganized and streamlined according to specific knowledge areas, forming relevant course clusters; by minimizing overlaps in similar content and eliminating unnecessary redundancy, the relationships among courses have become more coherent, with clear delineation of the topics each course should address, resulting in more focused and specialized curricula [20-24]. (3) An industry-education-integrated practical platform has been developed, establishing a multi-faceted environment that deeply integrates production, education, and research. The Yuanhua Practice Platform fosters the parallel advancement of engineering practice and innovative thinking. On campus, it establishes a simulation-based training center that replicates real-world engineering environments; off campus, it partners with industry to create hands-on platforms, enabling students to engage deeply in the entire project lifecycle—from initial planning to post-implementation evaluation—while immersing themselves at the forefront of cutting-edge technologies. Under the dual mentorship of faculty members and industry experts, students refine their interdisciplinary competencies, cultivating robust engineering capabilities and a spirit of innovation [25-29].

These reform initiatives have yielded significant results in enhancing the effectiveness of practical teaching, laying a solid foundation for cultivating new-engineering talent that meets the future demands of the construction industry, and providing other similar institutions with a replicable model for reforming practical instruction.

2 PROBLEMS IN THE PRACTICAL TEACHING OF CONSTRUCTION COST ENGINEERING AT PRIVATE UNIVERSITIES

2.1 The practical teaching system lacks systematicity and coherence

2.1.1 Insufficient curriculum system development

Our university's construction cost engineering program lacks a clear, systematic overall curriculum design. In terms of course organization, there is a lack of explicit connections and complementarity among the various courses, making it difficult for students to develop a coherent knowledge framework throughout their studies. For example, while courses such as structural design, construction technology, and project management are taught independently, they should ideally be integrated in real-world projects; however, the current teaching arrangement often overlooks this integration, leaving students unable to grasp the complexity of civil engineering from a holistic perspective.

2.1.2 Weak intrinsic connections among teaching components

There is a lack of close, intrinsic connections among the various components of practical instruction, and the different hands-on tasks often lack coherence. As a result, students find it difficult to transition smoothly from one task to the next, leading to gaps in their learning process. This inconsistency not only hinders the continuous acquisition of knowledge but also constrains the development of their practical skills. Moreover, practical teaching remains disconnected from industry needs, leaving students with skills that fail to meet real-world job requirements and thereby diminishing their employability.

2.2 The content of practical teaching lacks clarity and a progressive structure

2.2.1 Weak continuity in instructional content

Within the existing practical curriculum system, there is a lack of clear instructional pathways and hierarchical relationships, resulting in particularly weak connections and transitions between courses. Students struggle to effectively apply their prior knowledge and experience to the acquisition of new skills, leading to low learning efficiency. Moreover, some practical courses suffer from unclear teaching objectives, causing instructors to easily stray from the main focus during instruction and making it difficult for students to develop a coherent learning framework. This ambiguity in instructional goals further exacerbates the isolation among courses, undermining the coherence of practical teaching.

2.2.2 The difficulty and progression of the practical content are inadequately designed.

Some practical tasks are too simple to effectively enhance students' hands-on skills, while others are overly complex, exceeding students' actual capabilities and leaving them daunted and disengaged. Moreover, the lack of a progressive structure in the practical content means that, after completing a series of tasks, students often fail to perceive significant improvements in their skills or knowledge, thereby undermining their motivation to continue learning.

2.3 Scarcity and Instability of Practical Teaching Resources

2.3.1 The development of the teaching faculty is lagging behind.

Private universities lack systematic planning in faculty development; their training programs lag behind industry needs, and the delivery methods remain overly uniform. Newly hired young faculty members generally lack practical engineering experience and have limited understanding of project workflows and technical details, making it difficult for them to effectively teach hands-on courses. Moreover, some instructors also fall short in pedagogical approaches and classroom management, struggling to engage students. Students' lack of interest and motivation results in a dull classroom atmosphere and poor teaching outcomes.

2.3.2 Insufficient teaching facilities and practical training bases

The civil engineering sector is placing increasingly stringent demands on technical equipment and practical learning environments, yet private universities struggle to keep pace in terms of investment in hands-on teaching resources. A lack of state-of-the-art equipment and innovative practice platforms that simulate real-world engineering settings limits students' opportunities to engage with and master cutting-edge technologies. Moreover, the instability of off-campus internship sites poses a significant challenge: constrained by limited financial resources and networking capabilities, private institutions find it difficult to establish long-term partnerships with major enterprises or organizations, thereby hindering students' access to sufficient practical experience during their studies.

3 REFORM OF PRACTICAL TEACHING IN THE CONSTRUCTION COST ENGINEERING MAJOR

3.1 Construction of a Tiered Practical Teaching System

The original practical teaching system was largely centered on theoretical courses, with practical courses often serving as supplements to and validations of theoretical knowledge, lacking both independence and systematic structure. This horizontal instructional model overlooks the continuity and progressive nature of students' competency development, resulting in a lack of intrinsic connections among practical teaching components and making it difficult to achieve effective integration and application of knowledge.

This study constructs a tiered practical teaching system centered around the sequence “professional foundational practice—professional practice—engineering practice.” By employing a backward design approach, the system specifies the engineering and innovation competencies required for graduation and maps them onto the professional practice curriculum. This framework transcends the traditional boundaries of individual practical courses, establishing both vertical linkages among them and horizontal cross-disciplinary connections, thereby forming a networked, interwoven curriculum structure. During implementation, in response to the distinct characteristics of students at different stages of learning, the system is designed according to a three-tiered architecture of “cognition–exploration–innovation”, with the specific process unfolding as follows:

- **Professional Foundation Practice Phase:** During the first year, students primarily acquire fundamental skills in reading two-dimensional architectural drawings, using CAD for drafting, and conducting three-dimensional spatial measurements through courses such as “Engineering Drawing and CAD Practice” and “Civil Engineering Surveying Practice.” These courses not only lay a solid foundation for subsequent studies but also guide

students in transitioning from two-dimensional thinking to three-dimensional spatial visualization, thereby fostering an initial capacity for spatial cognition.

- Professional Practice Phase: Starting in the second year, students begin taking core courses such as “Building Construction” and “BIM – Building Information Modeling.” These courses transform 2D CAD models into 3D architectural models, enabling students to gain an in-depth understanding of the relationship between a building’s structure and its functions, and to master the application of BIM technology in architectural design. Through hands-on practice, students’ professional skills and overall competencies are significantly enhanced.
- Engineering Practice Phase: During the third year, students are required to complete comprehensive courses such as “Engineering Project Management Practice,” “Civil Engineering Construction Practice,” and “Construction Measurement and Cost Estimation Practice.” These courses integrate 3D models with multidimensional factors—including time, quality, and economics—to comprehensively simulate the actual operational processes of engineering projects. By participating in real-world project management, construction simulations, and cost estimation exercises, students further develop their engineering practice skills and teamwork abilities.
- Comprehensive Application and Innovation Stage: The senior-year internship and capstone project constitute the advanced phase of the entire practical education system. Under the guidance of their supervisors, students are expected to integrate the knowledge and skills they have acquired and independently complete a full-scale engineering design or research report. This process not only assesses students’ professional competence and practical abilities but also fosters their innovative mindset and capacity to tackle complex engineering challenges.

The tiered practical teaching system has the following characteristics: Starting from the program’s learning outcomes, it adopts a backward-design approach to structure the practical curriculum and define its content, ensuring that each course contributes to the attainment of students’ ultimate competencies. By introducing independent yet coherent specialized laboratory modules, it establishes an interwoven network of courses, strengthening both vertical integration among practical courses and horizontal cross-disciplinary connections. A modular teaching approach is employed. The curriculum is structured so that each module is both independently functional and closely interconnected, enabling students to engage in selective learning based on their personal interests and career aspirations. By integrating the entire lifecycle of construction projects into practical instruction, students’ hands-on experience and engineering awareness are strengthened. Through a systematic review of course alignment, courses that only supported a single competency have been phased out, while a series of distinctive, comprehensive practical courses—such as the application of Guanglianda cost-estimation software and the integrated use of BIM—have been introduced to enhance students’ professional skills and innovative capabilities.

3.2 Systematically organize knowledge points, reconstruct the knowledge graph, and optimize the content of practical instruction

Guided by competency requirements and constrained by comprehensive coverage of all key concepts, this approach has refined the practical teaching curriculum, addressing issues such as disjointed or redundant content and suboptimal learning outcomes, while effectively resolving the challenges of reducing instructional hours and integrating knowledge points. Based on the logical relationships and complementarity among knowledge points, tightly interconnected course clusters have been established. This approach effectively reduces overlap and redundancy across courses, enabling each course to focus on its specific core themes and achieving a more focused and specialized curriculum. At the same time, the coherence among courses has been significantly enhanced, providing students with a clear and well-organized framework for their knowledge base.

Taking the entire lifecycle of a construction project as an example, during the investment decision-making phase, students prepare a corresponding feasibility study report as part of their engineering economics course design. Once the project is deemed feasible, they proceed to the design phase and then undertake the architectural design course project. In this architectural design component, when developing the building’s structural elements, students must take into account the subsequent structural design plan. Similarly, in the structural engineering course design, students are expected to build upon the creative outcomes from the earlier architectural design, helping them recognize that structural design must be closely integrated with architectural considerations—going beyond mere theoretical calculations. This approach fosters a holistic perspective, enhances logical thinking, and strengthens practical problem-solving skills. Upon completion of the design phase, the project moves into the bidding stage, during which students undertake both a civil engineering construction course project and a bidding-and-tendering course project. Drawing on the architectural and structural designs developed earlier, students produce complete construction drawings and prepare corresponding civil engineering construction organization plans. In the bidding phase, in accordance with the provisions of the Tendering and Bidding Law and the actual procedures currently employed in construction project tendering and bidding, students simulate the entire process—ranging from tender issuance and bid submission to bid opening, evaluation, and award—so that they can more quickly adapt to roles in the bidding and tendering field after graduation. Once the construction phase begins, students engage in hands-on sandbox simulations

of project management and practice using cost-estimation software, while also expanding their proficiency in applying BIM 5D to construction management. Finally, during the completion and acceptance phase, students prepare the requisite final project settlement and financial closing documents. A series of courses is meticulously structured around the project lifecycle, with each stage seamlessly integrated and mutually reinforcing, providing students with comprehensive training that spans from theory to practice and from the local to the global. This pedagogical approach not only bridges the gap between theory and practice but also effectively enhances students' engineering competence and innovative capabilities, laying a solid foundation for their future career development.

3.3 Building a practical resources system

This paper proposes establishing a practice-oriented teaching team that emphasizes engineering practice and the development of innovative capabilities, regularly updating engineering-based laboratory projects, strengthening the teaching resource repository, and improving the practical training platform. The scarcity of civil engineering-related teaching resources, particularly the lack of advanced technologies and innovative hands-on learning environments, has constrained students' ability to tackle complex engineering problems (Zhang & Zhao, 2018). Moreover, private universities face challenges in establishing stable off-campus internship bases and recruiting experienced faculty, further limiting improvements in the quality of practical instruction. This paper addresses the construction of a civil engineering-related practical resources system at the School of Business and Commerce through the following approaches.

3.3.1 Strengthen faculty development and build a “dual-qualified” teaching team.

By implementing a talent development strategy of “internal training plus external recruitment,” the college has actively integrated corporate engineering resources, thereby building a “dual-qualified” teaching team that excels in both theoretical instruction adherence. On campus, core faculty members and dual-qualified instructors work hand in hand: specialized teachers lead the theoretical curriculum, while industry experts are deeply involved in hands-on and design-oriented courses, creating a synergy of complementary strengths. Off campus, internship bases have been established with more than 40 enterprises, and 23 senior technical professionals from these companies serve as part-time instructors—such as Professor Zhu Shifeng from China Communications Construction Special Engineering Co., Ltd.—bringing real-world industry expertise to practical teaching. In addition, enterprise trainers are regularly invited to the school to deliver specialized skills workshops, enhancing faculty members' cutting-edge industry knowledge and competencies. Several faculty members have earned BIM professional qualification certificates and advanced assessor certifications, further strengthening the practical teaching team's capabilities.

3.3.2 Establish an engineering project case library to strengthen the cultivation of practical skills and innovation.

In response to the practical teaching needs of the construction cost estimation major, a project-based case library has been developed, featuring diverse content and a clear hierarchical structure. This library covers all stages of the project lifecycle, from foundational infrastructure to complex architectural design, and from preliminary feasibility studies and planning to construction management and operations and maintenance, aiming to help students grasp the full scope of engineering practice through a wide range of case studies. The case library is carefully designed with a graduated level of difficulty, offering both introductory, basic cases and more challenging, comprehensive ones to meet the needs of students at different learning stages and with varying skill levels. Additionally, the college integrates outstanding research topics, project cases, and innovative designs from national-level BIM-related academic competitions into the library, leveraging competition-driven learning and teaching to stimulate students' creative thinking and foster a spirit of healthy competition.

3.3.3 Integrate online and offline resources to establish a diversified practical teaching model. Guided by the New Engineering paradigm, we have strengthened the deep integration of industry and education, aiming to consolidate both online and offline resources and thereby develop a comprehensive, multi-faceted practical teaching framework.

Online, leveraging “Internet Plus” technologies, a digital learning platform has been established, meeting the needs for resource sharing and personalized learning. By integrating public educational resources such as Construction Cloud Courses and China MOOCs, students can engage in online practice, pre-study, and preparation. Moreover, in light of the specific characteristics of the construction cost estimation major, tailored online courses have been actively developed. These courses not only cover core foundational subjects like civil engineering surveying, civil engineering construction, and construction regulations, but also include cutting-edge technical modules such as bidding and tendering practices and BIM-based architectural design. Through high-definition video instruction, interactive Q&A sessions, and online assessments, students can access education of comparable quality to classroom teaching from the comfort of their homes, thereby further enhancing both learning efficiency and outcomes. On campus, we have established a range of facilities, including the BIM Technology Comprehensive Training Center, the Smart Construction Site Sandbox Lab, the Engineering Management AR Sandbox Lab, and the Engineering Comprehensive Training Room. These spaces are

equipped with cutting-edge BIM software and VR-based design platforms, providing students with a three-dimensional, multidimensional learning environment. Here, students can engage in hands-on activities such as simulating complex building structures and virtually touring construction sites, gaining a deep understanding of structural principles and mastering construction processes. By replicating real-world bidding and tendering scenarios and procedures, students develop critical skills in preparing tender documents, formulating pricing strategies, and applying negotiation techniques—all within a simulated setting. This practice-oriented approach not only enhances students' engineering expertise but also strengthens their market competitiveness and fosters a spirit of teamwork. Establishment of Off-Campus Practical Teaching Bases: To enable students to gain hands-on exposure to real-world engineering projects and stay abreast of cutting-edge industry developments, the college has actively developed off-campus practical teaching bases. In collaboration with numerous renowned construction firms, it has set up multiple internship and training sites. Here, students can participate in the full lifecycle of actual engineering projects, encompassing design, construction, project management, and post-project evaluation. By directly engaging with core engineering technologies, tackling real-world challenges, and taking part in project management, students' practical engineering skills and innovative capabilities have been significantly enhanced.

3.3.4 Build a practice platform for industry–education integration to strengthen the cultivation of innovation and engineering capabilities.

Campus Platform Development: In recent years, the university has kept pace with industry-driven technological trends by establishing a series of modern, industry-aligned practical training centers, including the BIM Technology Comprehensive Training Center, the Smart Construction Site Sandbox Training Room, and the Engineering Management AR Sandbox Training Room.

and comprehensive engineering training labs, among others. These labs are not only equipped with state-of-the-art experimental apparatus but also feature a suite of industry-leading software from companies such as Glodon, including BIM-based civil and MEP quantity takeoff and cost estimation tools, rebar detailing and calculation simulation systems, BIM construction site-simulation software, BIM 5D, Zebra scheduling solutions, BIM tendering and bidding sandbox evaluation systems, and Guangxia CAD structural design software. Together, these resources provide students with an end-to-end learning platform that spans the entire project lifecycle—from design to construction, and from management to assessment. The university has also undertaken extensive renovations and upgrades to its foundational laboratories, such as the building materials lab, geotechnical lab, and engineering surveying lab. By adding new equipment and updating existing facilities, it ensures that laboratory instruction remains cutting-edge and highly effective. In particular, the structural and mechanics labs have been outfitted with high-end experimental instruments, offering students a robust platform to explore scientific principles and hone their engineering skills. Furthermore, in collaboration with industry leader Glodon, the university has co-established the “Digital Construction Industry College,” infusing the curriculum with cutting-edge industry knowledge, fostering students' innovative thinking, and strengthening their hands-on practical abilities. **Off-campus platform development:** We have established deep cooperative mechanisms with numerous construction enterprises, set up internship bases, and facilitated student internships and practical training within these companies, enabling the integration of theory and practice in real-world engineering contexts and enhancing students' ability to tackle complex, real-world engineering challenges. Currently, our institute collaborates with state-owned enterprises and renowned companies such as China Communications Wuhan Harbor Engineering Design Research Institute Co., Ltd. and Wuhan Second Aviation Bridge & Road Special Engineering Co., Ltd. on internship programs. In addition, we partner with universities like Wuhan University of Technology to build research platforms, and we have created a tripartite collaborative education framework—“university–enterprise–academia”—to optimize our joint talent-development model, foster synergies between education and scientific innovation, and cultivate students' comprehensive competencies. With strong support from Glodon Company Limited, we have been approved as a pilot institution for the “1+X” BIM vocational skills certification program. The development of on- and off-campus practice platforms has ensured the smooth implementation of all components of practical instruction, while also providing valuable resources for academic competitions, after-class reinforcement and extension activities, and independent extracurricular skill enhancement, thereby supporting the improvement of teaching effectiveness.

4 CONCLUSIONS

The practice-based teaching system for the construction cost engineering major has been restructured by integrating digital technologies into practical courses, establishing a tiered framework that progresses from foundational professional exercises to specialized practice and ultimately to real-world engineering applications. Simultaneously, by mapping out a knowledge graph, the coherence of the curriculum has been ensured while avoiding content overlap, thereby optimizing the content of practical instruction. A practice-resource system centered on industry–education integration has been developed, with active collaboration with industry associations and enterprises. Through stable partnerships with training bases and the recruitment of faculty members possessing extensive engineering experience,

the quality of practical instruction has been significantly enhanced. Following this reform, students' ability to tackle complex engineering challenges has been strengthened, and their innovative thinking has been further stimulated.

Through in-depth implementation of practice-based teaching, overall teaching quality has improved significantly, particularly in practical instruction. From 2018 to 2024, the entire college has received a total of 99 awards at or above the provincial level, including 4 Grand Prizes, 12 First Prizes, 22 Second Prizes, and 34 Third Prizes. Over the past six years, faculty members have guided students to participate in national and provincial-level academic competitions related to their courses, providing mentorship to more than 120 student participants. This new teaching model has boosted students' enthusiasm for engaging in various innovation and technology activities, yielding excellent results; some students have also undertaken Building Information Modeling (BIM) skills training and certification exams, earning BIM professional competency certificates. These achievements lay a solid foundation for their successful transition into professional careers.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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