

Industry-University Collaboration for Cultivating Vocational Undergraduate Talent in Intelligent Construction

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Abstract: The rapid development of intelligent construction is reshaping architectural engineering education in China. In response to national policies promoting the coordinated development of intelligent construction, building industrialization, and vocational undergraduate education, architectural engineering programs must go beyond traditional skill training and focus on cultivating students' integrated abilities in digital modeling, data-driven management, application of intelligent equipment, safety control, and sustainable construction. Based on policy analysis and recent research, this paper proposes an industry-education collaborative talent cultivation framework for vocational undergraduate architectural engineering education. The framework is organized around one core objective, two development lines, multi-stakeholder collaborative governance, and four integration paths, and further establishes a progressive project-based teaching model and a dynamic multi-stakeholder evaluation system. This study provides a practical reference for vocational undergraduate institutions to link curriculum reform with industrial upgrading and the cultivation of high-level technical and skilled talents.

Keywords: Vocational Undergraduate Education; Intelligent Construction; Architectural Engineering; Industry-Education Integration; Competency-Based Education

1. Introduction

Intelligent construction has become an important direction for the transformation and upgrading of China's construction industry. National policies emphasize the coordinated development of intelligent construction and building industrialization, and promote the application of digital design, building information modeling, intelligent equipment, prefabricated construction,

and green whole-life-cycle management in engineering practice[1]. At the same time, the revised Vocational Education Law of the People's Republic of China and related policy documents clarify that vocational undergraduate education should cultivate high-level technical and skilled talents who can connect research and development with production practice and solve complex practical problems[2-3].

For architectural engineering education, this transformation means that talent cultivation should not merely add a few digital courses to the traditional curriculum. Rather, programs need to reconstruct training objectives, course content, practical teaching, and evaluation mechanisms according to the competency requirements of intelligent construction. Existing research shows that emerging engineering talents in the construction industry need not only professional knowledge but also digital literacy, innovation ability, and collaboration ability[4]. Therefore, it is necessary for vocational undergraduate institutions to establish systematic industry-education integration mechanisms.

2. Enterprise Demand and Talent Competency Analysis

Intelligent construction is not equivalent to simple software operation. It involves digital modeling, cross-disciplinary collaboration, intelligent production and construction, structural and environmental sensing, quality and safety management, and sustainable renovation. International and national standards also increasingly emphasize the importance of information management, data interoperability, model checking, and whole-life-cycle information application. For example, ISO 19650 provides a framework for BIM-based information management[5], while China's digital twin and BIM software standards further emphasize the requirements of standardized data application in engineering scenarios[6-7]. Accordingly, vocational undergraduate

architectural engineering graduates should develop five competency areas: engineering fundamentals, digital application, intelligent construction technology, safety and sustainable management, and collaborative innovation. These competencies should be embedded in curriculum design, project training, and evaluation, rather than being treated as isolated and fragmented learning outcomes.

3. Industry-Education Collaborative Governance Framework

This paper proposes a cooperation framework. The framework includes one core goal, two main lines, multi-stakeholder coordination, and four integration paths.

The core goal is to train compound and innovative high-level technical and skilled talent in intelligent construction. Such talents should possess professional ethics, engineering knowledge, digital competence, practical skills, workplace adaptability, and innovation awareness. This objective should run through the entire process of curriculum design, teaching organization, practical training, and quality evaluation.

The two main lines refer to academic advancement and career development. Academic advancement emphasizes systematic knowledge learning, engineering reasoning, language expression, technical documentation, and integrated analysis abilities; career development emphasizes professional standards, skill certificates, post tasks, safety awareness, and practical performance. The two main lines should not be separated. For example, structural theory should be linked to BIM-based structural modeling; construction management theory should be linked to schedule simulation and site data; safety education should be linked to enterprise risk scenarios and inspection records. Through this connection, students can transform theoretical knowledge into workplace competence.

The Multi-stakeholder coordination covers universities, enterprises, industry associations, and public administration departments. Universities are responsible for program construction, curriculum development, theoretical teaching, teaching research, and academic quality assurance; enterprises provide real engineering tasks, equipment, technical standards, post mentors, and performance evaluation; industry associations can convey

industry trends, professional standards, and certification requirements; government departments provide policy guidance, resource support, and quality supervision. This structure can prevent enterprise participation from being reduced to graduate recruitment, making enterprises co-designers, co-teachers, and co-evaluators in the talent cultivation process.

The four integrations connect governance with teaching practice. First, professional education should be integrated with industrial development: course content must be updated according to changes in intelligent construction, BIM standards, prefabricated construction, smart site systems, and green construction requirements. Second, practical teaching should be integrated with enterprise tasks: real or simulated enterprise projects should be transformed into teaching projects, training modules, and assessment tasks. Third, teachers should be integrated with engineers and master craftsmen: university teachers need opportunities to participate in enterprise practice, while enterprise engineers should be invited to participate in curriculum development, project guidance, and evaluation. Fourth, competency evaluation should be integrated with the practical process: students should be evaluated not only on final examinations, but also on project process, digital outcomes, workplace behavior, and professional standards.

This collaborative framework conforms to the national requirements for school-enterprise joint construction of vocational undergraduate programs and substantive practical teaching[8], and also provides an institutional foundation for the continuous improvement of the curriculum.

4. Tiered and Progressive Project-Based Teaching Path

A standardized teaching method is essential to improve the practicality and operability of the school-enterprise cooperation framework. This study constructs a four-tier progressive project teaching system, including basic projects, professional projects, comprehensive projects and innovative projects. The system follows a step-by-step training logic. It guides students to master fundamental operational skills first, accumulate professional technical capabilities in the intermediate stage, undertake simulated workplace engineering tasks subsequently, and finally explore innovative solutions to practical industry problems.

Basic projects are designed for lower-grade students. They aim to cultivate students' foundational engineering literacy and preliminary practical ability. The core learning contents include engineering drawing reading, field data measurement, material performance testing, construction safety risk identification and simple construction scheme compilation. This teaching stage takes operational accuracy, normative compliance and construction safety as the core assessment criteria. Students are required to grasp basic reading skills of construction drawings, complete simple engineering quantity calculation, recognize conventional building materials, and strictly abide by industry technical specifications.

Professional projects focus on specialized technical scenarios of the industry. The main teaching tasks cover BIM modeling, structural mechanical analysis, construction schedule optimization, project cost estimation, engineering quality inspection and prefabricated component management. This module enables students to apply digital technical tools to simulated professional work. In specific practice, students can establish architectural and structural BIM models, verify the consistency of multi-dimensional model data, detect engineering collision problems, and sort out practical results to form standardized project reports.

Comprehensive projects are highly consistent with actual engineering construction scenarios. They require students to integrate multidisciplinary professional knowledge to solve systematic engineering problems. Students need to complete the compilation of construction organization schemes, coordinate the balanced control of project cost and construction progress, formulate targeted quality and safety supervision measures, and draft green building renovation plans. This training mode effectively strengthens students' team collaboration and cross-department communication skills, and realizes the organic integration of theoretical knowledge and engineering practice.

Innovative projects are derived from real enterprise engineering problems, discipline skill competitions and applied engineering research topics. This type of project encourages students to conduct method comparison, technical verification and tool innovation. Students can optimize traditional construction scheduling schemes based on actual field monitoring data, design intelligent digital inspection workflows,

and formulate BIM-based whole-process information transmission schemes for building operation and maintenance stages. The tiered project teaching path realizes the effective connection between classroom teaching and industrial practice. It also provides strong support for cultivating students' digital application capability, engineering practical competence and innovative thinking[9-11].

5. Dynamic Multi-Stakeholder Evaluation System

Traditional assessment approaches fail to fully measure core abilities required in intelligent construction. A student might pass written exams, yet struggle to coordinate digital models, read field data or tackle real-world engineering challenges. For this reason, we build a dynamic evaluation system with multiple participants.

University teachers form the first assessment group. They judge students on theoretical knowledge, technical reasoning, academic honesty, calculation precision and the quality of submitted documents. Enterprise mentors serve as the second group. They rate students on task completion, professional accountability, safety compliance, communication skills and readiness for actual job roles. The third group includes industry representatives and professional association experts. They check whether student work matches industry standards, technical codes and practical industry demands. The fourth group is students themselves. Through self-review and peer review, learners reflect on their learning journey, team contributions and the growth of professional competencies.

The evaluation combines formative and summative assessment. Formative assessment tracks practical training attendance, modeling precision, data integrity, safety awareness, team collaboration, project progress and problem-solving approaches. Summative assessment relies on final project deliverables, vocational skill certifications, on-the-job performance reports and oral defense presentations. Digital portfolios work well for intelligent construction teaching. They store drawings, BIM models, inspection logs, construction schedules, anonymized site photos, learning reflections, certificates and mentor comments. These portfolios capture students' development and supply supporting materials for curriculum review.

This evaluation system creates a closed feedback

cycle. If students repeatedly make mistakes in model data management, courses will add more content on information standards and model validation. If enterprises point out weak safety awareness, teachers will upgrade scenario-based safety training. If students lack communication skills, the program adds cross-disciplinary project presentations and technical writing exercises. Under this design, assessment supports ongoing teaching improvement instead of only giving a final score.

6. Implementation Strategies and Quality Assurance

These teaching practices rely on sound campus regulations and stable school-enterprise collaboration. They also fit the training goals of vocational undergraduate education. When designing courses, schools and enterprises do more than simply create a course catalog. They co-develop complete talent training schemes. These schemes define training objectives, course modules and sources of practical projects. Schools need to clarify credit rules. Students need clear guidance to earn credits through enterprise practice and vocational qualification certificates. Course content must keep pace with industry updates. Intelligent construction technology evolves quickly, so schools should set up a project resource library. The library holds real enterprise cases, BIM models and safety records. Enterprises often have concerns over data security. Schools need to protect sensitive data and sign formal cooperation contracts. These contracts set rules for data protection and intellectual property.

The teaching team needs both academic knowledge and hands-on experience. University teachers keep learning new intelligent construction tools and digital specifications. Enterprise engineers learn basic teaching skills and student assessment methods. Joint lesson preparation benefits both sides. Teachers deliver theoretical knowledge, while engineers share real work experience. This makes teaching more practical and closely linked to actual projects. Digital tools require careful use. Simulation platforms and digital portfolios support mixed learning, but cannot replace hands-on field practice. Technology serves experiential learning. Students still need skills for site observation and real problem-solving.

Quality assurance uses multiple inspection channels. Schools monitor teaching quality and

student learning outcomes. Enterprises and industry associations also provide feedback. Their input reflects graduate competency and post-graduation employment performance.

7. Discussion and Conclusion

This framework changes the meaning of industry-education integration. It does not see cooperation as only internships. It sees cooperation as shared curriculum governance. In this model, enterprises do more than provide practice places. They join curriculum design, help develop projects, guide students, and take part in assessment. This kind of cooperation can make classroom teaching closer to real engineering work. It can also help teaching keep up with changes in intelligent construction.

This framework also shows the special value of vocational undergraduate education. Compared with traditional academic undergraduate education, it focuses more on technology use, workplace ability, and practical problem solving. Compared with higher vocational education, it also needs stronger theory, better system thinking, and more innovation ability. Vocational undergraduate education should connect academic learning with professional training. This connection is important for training high-level technical and skilled workers. Several limitations should be noted. First, the framework proposed in this paper is derived from the practice of a single institution, and its applicability to vocational undergraduate programmes in other regions and discipline categories needs further verification. Second, this paper does not provide longitudinal data on graduate employment and career development, so the long-term effect of the tiered project-based teaching path remains to be tested. Third, the dynamic multi-stakeholder evaluation system involves indicators from universities, enterprises, and industry associations, and the weighting of these indicators has not been calibrated with large-sample data. Future research can advance in three directions: conducting multi-institution comparative case studies to examine the adaptability of the framework under different industrial bases; tracking successive cohorts of graduates to assess the sustained influence of project-based teaching on professional competence; and constructing a quantifiable evaluation index system to support the iterative improvement of the collaborative governance mechanism.

The implementation of this framework also depends on several preconditions. A stable school-enterprise cooperation agreement provides the institutional basis for joint curriculum design and shared practical training bases. Teaching staff with both academic qualifications and engineering experience determine whether project-based teaching can be carried out at the expected depth. Digital teaching resources, including building information modeling platforms and virtual simulation systems, influence the feasibility of tiered projects in routine teaching. When these conditions are not yet fully met, institutions can start with individual modules, for example by introducing enterprise mentors into professional projects or piloting the evaluation system in selected courses, and then extend the experience to the whole programme once the supporting mechanisms improve.

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