International Journal of Education and Social Development
ISSN: 3078-9931 (Print), ISSN: 3078-2287 (Online) | Vol. 6, No. 3, 2026

Research on the Talent Training Model for Master's Degree in Civil and Hydraulic Engineering under the Background of Intelligent Construction

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Abstract: With the rapid advancement of technologies such as artificial intelligence, big data, and cloud computing, intelligent construction has become a pivotal direction for the transformation and upgrading of the civil and hydraulic engineering industry. This paradigm shift transcends mere technological adoption, representing a fundamental restructuring of project lifecycle management, from conceptual design and precise planning to efficient execution, sustainable operation, and intelligent maintenance. Consequently, this transformation poses multifaceted and profound new demands for industry professionals, necessitating a corresponding evolution in higher education, particularly at the postgraduate level where specialized expertise is honed. This paper aims to explore the reform and innovation of the cultivation model for Civil and Hydraulic Engineering Professional Master's students under the backdrop of intelligent construction. It begins by conducting a systematic analysis of the evolving talent demands of the industry, identifying key competency gaps. Subsequently, by synthesizing relevant domestic and international research findings, pedagogical theories, and pioneering practical experiences from engineering education, a comprehensive framework of targeted teaching reform measures is proposed. This framework encompasses curriculum redesign, pedagogical innovation, practical training enhancement, and mentorship restructuring. The ultimate goal is to cultivate a new generation of high-level, interdisciplinary specialists who possess not only solid theoretical foundations in their core discipline but also outstanding practical capabilities in applying intelligent technologies, coupled with a robust innovative spirit and adaptive problem-solving skills. Such a cultivated talent pool is deemed essential for providing robust and sustainable intellectual support for the ongoing and future development of the intelligent construction field.

Keywords: Intelligent Construction, Civil and Hydraulic Engineering, Master's Talent Cultivation, Teaching Reform, Interdisciplinary Education.

1. Introduction

This macro-environment creates a pressing imperative for academia. The traditional cultivation model for Civil and Hydraulic Engineering Professional Master's (M.Eng.) talents, often heavily oriented towards conventional theories and practices, urgently needs to adapt to the new competency requirements precipitated by industry development. There exists a growing disconnect between the skills imparted by educational institutions and the multifaceted expertise demanded by the modern, technology-driven construction landscape. Therefore, enhancing the quality, relevance, and agility of talent cultivation through systemic and innovative teaching reform is not merely an academic exercise but a crucial mission for supplying a competent pipeline of high-quality professionals to the field of intelligent construction. This paper delves into this critical issue, analyzing the specific demand shifts, diagnosing existing gaps in current educational practices, and proposing a holistic set of reform measures, illustrated by a practical case study.

In recent years, with the increasing demand for high-level applied talents in China's civil and hydraulic engineering, the training mode of professional master's degree students has become a research hotspot. Through the analysis of 14 literature, it was found that the research mainly focuses on the following themes: (1) innovative training models and school enterprise collaboration; (2) Construction of curriculum system and practical platform; (3) Vocational competence and innovation and entrepreneurship education; (4) The characteristic practice of local colleges and universities; (5) Ideological and Political Education and Case Teaching. More details can be found in Table 1.

Table 1. Literature related to Master's degree in Civil Engineering and Hydraulic Engineering

Reference No.	Author(s) (Year)	Key Findings
[1]	Bian Yadong et al. (2020)	Significant improvements in management system reform and supervisor competency enhancement.
[2]	Yue Jianwei et al. (2021)	Initial implementation of industry-university collaborative cultivation achieved.
[3]	Yang Xiujuan et al. (2021)	Proposed specific pathways for cultivating innovative thinking and abilities.
[4]	Luo Yunju et al. (2022)	Improvement in the effectiveness of vocational ability cultivation.
[5]	Wu Xiufeng et al. (2022)	Formed a framework combining knowledge chain and innovation domain.
[6]	Yu Boting et al. (2023)	Engineering practical ability significantly improved.
[7]	Xiao Henglin et al. (2023)	Provided a replicable paradigm for leadership cultivation.
[8]	Hou Gangling et al. (2023)	Innovative practice platform design received recognition from enterprises.
[9]	Yao Baolin et al. (2024)	Improvement in the quality of talent cultivation at local institutions.
[10]	Song Kezhi et al. (2024)	Provided teaching resources integrating ideological education with professional knowledge.
[11]	Yu Jingfei (2024)	Addressed key node issues in talent cultivation.
[12]	Deng Xianghui et al. (2025)	Enhanced the capabilities of students, teachers, and enterprises.
[13]	Zheng Deqian et al. (2025)	Cultivation of high-level application-oriented talents adapted to industry needs.
[14]	Zheng Wen et al. (2025)	Solved the problems of implementing ideological education and the evaluation system.

2. Changing Talent Demands in the Civil and Hydraulic Engineering Industry under Intelligent Construction

The advent of intelligent construction is fundamentally reshaping the profile of the ideal engineering professional. The demand has evolved from specialists with deep but narrow domain knowledge to versatile integrators who can bridge the gap between civil engineering fundamentals and cutting-edge digital technologies.

2.1. Enhanced and Diversified Demand for Technical Competencies

The field of intelligent construction involves the deployment and integration of a wide array of high-tech applications. Beyond the now-essential BIM for 3D modeling, coordination, and 4D/5D simulation, professionals must engage with IoT sensors for real-time data acquisition, 3D printing for automated construction, drones for site surveying and monitoring, big data platforms for analyzing performance and predicting risks, and AI algorithms for optimizing design, scheduling, and maintenance. The application of these technologies requires professionals to possess more than just awareness; they need solid technical skills and the proactive ability to understand, select, and apply appropriate smart technologies to solve real-world engineering problems. For instance, BIM technology has evolved from a visualization tool to a cornerstone of digital project delivery, making advanced proficiency in BIM management, interoperability, and customization a necessary skill for Civil and Hydraulic Engineering Master's students. Furthermore, as intelligent construction technology continues to evolve at a rapid pace, the demand for continuous learning and adaptability in technical competencies will keep increasing. Familiarity with concepts like Digital Twins (creating dynamic virtual replicas of physical assets) and modular construction is also becoming increasingly important.

2.2. Increased Requirement for Systemic Interdisciplinary Literacy

Intelligent construction is inherently the product of deep integration of multiple disciplines. It no longer rests solely on civil engineering principles but actively involves materials science (for smart materials), electronic information engineering (for sensor networks and embedded systems), computer science and technology (for software development, data structures, and cloud computing), mechanical design and automation (for construction robotics), and even data science and management studies. Therefore, professionals need to possess genuine interdisciplinary literacy. This goes beyond superficial exposure; it requires the cognitive ability to understand the languages and constraints of adjacent fields, enabling them to skillfully synthesize and apply knowledge from these various domains to model, analyze, and solve complex, system-level problems. This interdisciplinary competence is fundamental for effective communication, collaboration, and co-creation with different specialists—architects, software developers, data scientists—in intelligent construction projects. It is also the key to driving holistic innovation within the industry, moving beyond incremental improvements in isolated tasks.

2.3. Emphasis on a Synergy of Innovative Spirit, Practical Ability, and Managerial Acumen

The field of intelligent construction is one of constant innovation, exploration, and implementation. It requires professionals to possess a dual-capacity: innovative thinking to conceive novel solutions and flexible, adaptable practical operational skills to implement and iterate those solutions in messy, real-world contexts. Professionals should be able to promptly identify inefficiencies or problems in traditional processes, propose independent, novel, and effective technology-enabled solutions, and possess the project management and entrepreneurial insight to see them through to fruition. This involves understanding lifecycle costing, change management in digital workflows, and stakeholder coordination. Hence, equal and synergistic emphasis on innovative spirit, hands-on practical ability, and emerging digital project management acumen has become a crucial, composite requirement for talents aiming to lead in intelligent construction.

3. Critical Analysis of Existing Problems in the Current Cultivation Model for Civil and Hydraulic Engineering Professional Master's Talents

Despite the clear shift in industry demands, a significant lag exists in many academic programs, leading to several systemic shortcomings in the current cultivation model.

3.1. Insufficient and Superficial Interdisciplinary Integration

Currently, a majority of universities exhibit insufficient depth in interdisciplinary integration within their cultivation processes for Civil and Hydraulic Engineering Professional Master's students. The curriculum structure often remains siloed, with "intelligent" topics occasionally added as isolated elective courses rather than being woven into the core engineering fabric. This approach fails to meet the demand for deeply integrated interdisciplinary talents. The result is that students may gain fragmented knowledge of new tools but lack the comprehensive interdisciplinary literacy and systems-thinking mindset needed to address complex issues where civil engineering problems are inherently coupled with data and software challenges. They learn about the technologies but not how to think with them as an integral part of the engineering process.

3.2. Lagging Teaching Content and Pedagogical Methods

The pace of technological change often outstrips curriculum renewal cycles. Consequently, teaching content and methods in many institutions lag behind industry development, failing to promptly incorporate the latest knowledge, standards, and case studies from the frontier of intelligent construction. Pedagogical approaches often remain traditional, centered on lectures and standardized problem sets, which are ill-suited for teaching dynamic, project-based, technology-applied subjects. This dissonance leads to a skills gap where graduates often struggle to adapt to industry demands, lacking not only necessary up-to-date technical skills but also the experiential learning and adaptive mindset required to apply them in practice.

3.3. Weak, Disconnected, and Under-Assessed Practical Training Components

Practical training is a vital pathway to enhance students' hands-on abilities, innovative confidence, and understanding of real-world constraints. However, in the current cultivation process at many universities, practical components are often inadequately emphasized, treated as ancillary rather than central. There is frequently a lack of robust, co-designed practical bases established through deep, sustained cooperation with industry partners. When they exist, internships or practice sessions can be observational rather than participatory. This leads to ineffective improvement in students' practical abilities and their capacity to navigate the complexities of technology implementation on site. Moreover, assessment of these practical components is often simplistic, failing to evaluate the higher-order competencies of integration, problem-solving, and innovation in a technology-rich context.

4. A Holistic Framework of Reform Measures for the Cultivation Model

To bridge the identified gaps, a multi-pronged, synergistic reform framework is necessary, targeting curriculum, pedagogy, practice, and mentorship.

4.1. Reforming Teaching Content and Pedagogical Methods

4.1.1. Dynamic Integration of New Knowledge and Technologies

A proactive mechanism for curriculum evolution must be established. Teaching content should be updated promptly based on developments in intelligent construction, introducing new knowledge stacks such as BIM (Levels 2 & 3), IoT sensor networks and protocols, big data analytics for construction, fundamentals of AI/ML for engineering applications, and robotics in construction. This can be achieved not only by offering dedicated new courses but, more importantly, by infusing these topics into core courses like structural design, project management, and construction methods. Regular industry seminars, workshops with technology vendors, and analysis of cutting-edge case studies should be mandatory components to ensure teaching content remains synchronized with industry needs, allowing students to keep abreast of the latest technological trends and application skills.

4.1.2. Implementing Deep Interdisciplinary Integrated Teaching

Breaking down traditional disciplinary barriers requires structural change. Implementing true interdisciplinary integrated teaching involves co-teaching by faculty from engineering and computer science, developing joint modules, and defining shared learning outcomes. Offering cross-disciplinary elective clusters or certificates can promote deeper exchange. Organizing interdisciplinary problem-solving seminars and hackathons on themes like "Digital Twin for Infrastructure Resilience" can enhance students' comprehensive literacy and collaborative problem-solving abilities. Students should be consistently encouraged and provided frameworks to transcend disciplinary boundaries in their coursework and research, fostering an ingrained interdisciplinary thinking mode and hybrid research methodology.

4.1.3. Adopting Student-Centered, Active Learning Methods

To stimulate student interest, initiative, and deeper learning, diverse teaching methods must replace passive lecturing. Case-based teaching using real intelligent construction project data, project-based learning (PBL) where students tackle semester-long, open-ended challenges, flipped classrooms for foundational knowledge, and simulation-based learning using professional software are highly effective. Through detailed case analysis and extended project practice, students can be guided to integrate theoretical knowledge with practical application, thereby improving their technical, practical, and innovative capabilities. Emphasis should also be placed on cultivating students' critical thinking, systems analysis, and complex problem-solving skills to better prepare them for the ambiguous and dynamic environment of intelligent construction.

4.2. Strengthening and Systematizing Practical Teaching Components

4.2.1. Establishing Strategic University-Enterprise Cooperative Practice Ecosystems

Moving beyond ad-hoc partnerships, institutions must actively cultivate strategic cooperation with leading enterprises, research institutes, and technology providers to establish joint, state-of-the-art practice bases or innovation labs. These ecosystems enable true resource sharing and complementary advantages. They provide students with authentic or near-authentic engineering practice environments, such as access to cloud-based BIM collaboration platforms, IoT kits for lab experiments, or sandbox environments with construction data. This allows students to gain in-depth, hands-on understanding of the application, limitations, and operational workflows of intelligent construction technologies, enhancing their practical skills and professional qualities. Close cooperation also embeds students in real industry challenges and development trends, preparing them for future career trajectories.

4.2.2. Designing Rigorous Assessment for Practical Learning Outcomes

Practical components must be formally and weightily incorporated into the curriculum system, with clear, independent practical credits linked to defined competency outcomes. Comprehensive assessment should move beyond simple participation. It can include detailed portfolios documenting process and learning, technical reports on practical projects, presentations and demonstrations of solutions, and structured evaluations from industry mentors. This multi-faceted assessment evaluates not just task completion but also problem-solving, innovation, and professional conduct. Guidance, mentoring, and structured reflection during the practical process are crucial to ensure students fully engage and achieve substantive, transferable learning and skill improvement.

4.3. Building a Diversified and Collaborative Supervisor Team

4.3.1. Forming Functioning Interdisciplinary Supervisor Teams

The mentorship model must evolve. Formally constituted interdisciplinary supervisor teams should be established, involving experts and scholars from civil engineering, computer science, data analytics, and experienced professionals from the industry (e.g., lead BIM managers, digital innovation officers) to jointly guide Master's students, especially during their thesis or capstone projects. Collaborative guidance from such teams exposes students to diverse perspectives, enhancing their comprehensive literacy and innovative capabilities. Supervisor teams should be incentivized to jointly apply for and undertake interdisciplinary research projects and practical activities, providing students with natural opportunities for embedded, interdisciplinary learning and practice.

4.3.2. Implementing and Supporting an Effective Dual-Supervisor System

A well-supported dual-supervisor system should be a standard feature. It combines an academic supervisor (from the university, ensuring theoretical rigor and academic standards) with an industrial supervisor (from an enterprise, providing practical relevance, current industry context, and professional networking). This system ensures students receive balanced guidance and support in both theory and practice. The industrial supervisor's practical experience and industry connections are invaluable for providing students with realistic project topics, data access, and critical career development advice. Formal channels for regular communication between the two supervisors are essential for the model's success.

4.4. Cultivating an Ecosystem for Innovation and Entrepreneurial Mindset

4.4.1. Embedding Research and Innovation in the Curriculum

Students should be systematically encouraged and provided resources to participate in research and innovation activities. This includes dedicated project courses, support for entering academic competitions (e.g., on sustainable design with AI), guidance on publishing in applied research journals, and workshops on intellectual property and patent application processes. These activities are not extracurricular but are integrated to enhance students' innovative thinking, research methodology, and practical abilities. Necessary technical, financial, and mentorship support should be provided to help students achieve substantive, meaningful outcomes and gain valuable experience during the innovation process.

4.4.2. Offering Contextualized Innovation and Entrepreneurship Education

Courses on innovation management and entrepreneurship tailored for the built environment should be offered. These courses move beyond generic business plans to teach fundamental knowledge and skills in technology commercialization, startup finance for contech, lean methodology applied to construction problems, and leadership in digital transformation. Through case studies of successful contech startups and simulated entrepreneurship projects, students' entrepreneurial awareness and capabilities can be fostered. Additionally, providing access to business incubation services specifically for the construction sector offers tangible support and assistance for student startups. These initiatives aim to stimulate students' entrepreneurial enthusiasm and innovative spirit, cultivating them into intrapreneurs (driving change within established companies) or entrepreneurs who can become interdisciplinary talents with both innovative capability and practical experience.

5. An In-Depth Case Study: Talent Cultivation Practices for the Intelligent Construction Major at the School of Civil Engineering, Sichuan University of Science & Engineering

The School of Civil Engineering at Sichuan University of Science & Engineering (SUSE) serves as an illustrative example of proactive adaptation. It has actively responded to national strategic plans and the development needs of the intelligent construction field, exploring new pathways for cultivating talents within the context of "Emerging Engineering Education" (3E).

5.1. Systemic Restructuring of the Curriculum System

The school undertook a fundamental restructuring of the curriculum system for its Intelligent Construction major. The approach was integration-centric: intelligent applications were not merely appended but deeply integrated around the enduring core of civil engineering principles. While rigorously cultivating students' professional knowledge and expertise in structures, geotechnics, and materials, multidisciplinary knowledge from computer science and data analytics was systematically incorporated. New interdisciplinary courses such as "Intelligent Construction Technology and Systems," "Big Data Analysis and Application in Construction," and "Artificial Intelligence & Machine Learning for Civil Engineering" were added as core or required electives. Furthermore, the school promotes interdisciplinary research practices, with faculty and students actively involved in developing applied platforms like City Information Modeling (CIM) platforms for local governments and smart construction site data monitoring platforms. These initiatives provide students with hands-on practical opportunities and meaningful research platforms from their early studies, effectively fostering their interdisciplinary comprehensive literacy and complex problem-solving abilities.

5.2. Development of an Integrated Practice and Competition Ecosystem

The school has cultivated strategic collaborations with leading industry players such as China Construction Eighth Engineering Division Corp., Ltd. and Nanjing Yangtze River Urban Architectural Design Co., Ltd. to establish stable, university-enterprise cooperative practice bases. These are not merely sites for internships but are involved in joint curriculum development and project sponsorship. This cooperation provides students with immersive, real engineering practice environments. Complementing this, the school actively hosts and prepares students for high-profile national disciplinary competitions like the National Graphic Modeling Competition and the National BIM Graduation Design Innovation Application Competition. Participation in these competitions elevates students' BIM application skills, digital modeling proficiency, and Informationization level under competitive, project-based conditions. This dual strategy of deep industry practice and competitive skill sharpening has proven effective in improving students' practical abilities and laying a solid foundation for their future career development and adaptability.

5.3. Building a Cohesive and Supportive Supervisor Network

Recognizing the importance of mentorship, the school has formally established interdisciplinary supervisor teams. These teams include core civil engineering faculty, faculty from computer science departments, and senior engineers or project directors from partner enterprises. They participate collectively in guiding Master's students' thesis work and major projects. Collaborative guidance ensures that student research is both academically sound and practically relevant. The school robustly implements the dual-supervisor system, with clear guidelines on roles and communication protocols. Academic supervisors anchor the theoretical and methodological rigor, while industrial supervisors provide continuous practical feedback, access to real-world data/scenarios, and career mentoring. This structured support system helps students better integrate theoretical knowledge with practical application and provides strong, multifaceted support for their professional development.

5.4. Cultivating a Culture of Innovation and Entrepreneurial Action

The school emphasizes translating knowledge into innovation. It offers dedicated courses on innovation and entrepreneurship in engineering and provides access to the university's business incubation services, with some tracks focused on technology commercialization. These initiatives are designed to stimulate students' entrepreneurial enthusiasm and innovative spirit. The school actively organizes and sponsors student teams to participate in various innovation and entrepreneurship competitions at provincial and national levels, as well as in practical activities like innovation workshops with industry. This focus aims to cultivate graduates who are not just job-seekers but also innovative thinkers and potential job-creators, equipped with both the technical ability and the mindset to drive change in the intelligent construction landscape.

6. Conclusion and Future Prospects

In conclusion, reforming and innovating the cultivation model for Civil and Hydraulic Engineering Professional Master's talents is an urgent and inevitable requirement under the irreversible trend of intelligent construction. This paper has argued that a piecemeal approach is insufficient. Instead, a holistic framework encompassing the reform of teaching content and pedagogical methods, the strengthening and systematization of practical teaching components, the building of diversified and collaborative supervisor teams, and the cultivation of an innovation and entrepreneurial ecosystem can effectively bridge the current competency gaps. When implemented synergistically, these measures can significantly enhance the quality, relevance, and impact of talent cultivation, thereby supplying a steady stream of high-quality, adaptable professionals to the field of intelligent construction.

Looking ahead, the journey is one of continuous adaptation. As intelligent construction technologies continue to develop at an accelerating pace and industry demands constantly evolve, the cultivation model itself must embody agility and a commitment to lifelong learning. Future efforts must focus on several fronts: Firstly, establishing more flexible and dynamic curriculum update mechanisms to incorporate the latest intelligent construction technologies and concepts rapidly. Secondly, deepening and institutionalizing cooperation with enterprises and the industry to move beyond projects to co-create curricula and even micro-credentials, establishing closer university-enterprise practice bases and joint research centers. Thirdly, a sustained emphasis on cultivating students' interdisciplinary systems thinking, ethical considerations around data and AI, adaptive learning skills, and innovative capabilities will remain paramount. The ultimate goal is to develop high-level, interdisciplinary specialists who are not only technically proficient but also possess the strategic vision, collaborative spirit, and innovative drive to lead. Such a talent pipeline is essential for providing sustained and powerful intellectual impetus for the advancement of the intelligent construction field, ultimately contributing to building a more efficient, sustainable, and resilient built environment.

Acknowledgments

This research is supported by the Collaborative Education Project of Industry University Cooperation by the Ministry of Education of China (NO. 231000340213903, 240902725231826, 241001153234556).

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