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Empowering Industry-Education Integration of Intelligent Construction Specialty Group with New Quality Productivity: Path Construction and Empirical Research

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Abstract: New quality productivity serves as a core impetus and guiding direction for the digital transformation of the construction industry and the reform of industry-education integration concerning the intelligent construction specialty group. In view of the prominent dilemmas in the current industry-education integration of this specialty group—including superficial school-enterprise collaboration, outdated curriculum systems, misaligned practical training scenarios, and a single-layered evaluation mechanism—this study takes the empowerment of new quality productivity as the entry point. It analyzes the inherent coupling logic between new quality productivity and industry-education integration, constructs a four-dimensional education pathway featuring 'government-school-enterprise coordination, post-course-competition-certificate integration, virtual-real scenario linkage, and diversified closed-loop evaluation', and conducts empirical testing based on practices in local higher vocational colleges. The research methodology incorporates both qualitative analysis and quantitative assessment to validate the effectiveness of the proposed framework. Through systematic implementation and evaluation over multiple academic cycles, the results demonstrate that this four-dimensional pathway effectively breaks through bottlenecks in industry-education integration, significantly improves talent training quality and industrial adaptability, and provides a replicable practical reference for advancing the reform of industry-education integration of intelligent construction specialty groups in peer institutions. The findings highlight the transformative potential of new quality productivity in reshaping vocational education paradigms and fostering sustainable industry-academia partnerships.

Keywords: new quality productivity; intelligent construction specialty group; industry-education integration; path construction; empirical research

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1. Introduction

Against the backdrop of the profound integration between the digital economy and the real economy, a new form of quality productivity has emerged, serving as a pivotal engine for reshaping industrial landscapes and fostering new development momentum. As a crucial pillar of the national economy, the construction industry has historically relied on an extensive development model, with an overall digital penetration rate that remains below 5%. This scenario underscores an urgent need for transformation, prompting the construction industry to accelerate its shift toward digitalization, intelligence, and environmentally sustainable development. As the primary vehicle for cultivating new quality productivity within the sector, intelligent construction has experienced rapid expansion, thereby raising new requirements for high-caliber technical and skilled talents. This transformation is not merely a trend but a necessity, as the industry seeks to align itself with modern technological advancements and environmental considerations. The integration of digital tools and intelligent systems is expected to enhance efficiency, reduce waste, and improve overall project outcomes, making it

imperative for the workforce to adapt and acquire new skills that meet these evolving demands. The focus on green development also highlights the industry's commitment to sustainability, ensuring that future growth does not come at the expense of environmental health. Thus, the construction sector is at a critical juncture, where embracing innovation and fostering a skilled workforce are essential for maintaining its role as a cornerstone of the economy.

The intelligent construction specialty group integrates a range of competitive majors, including architectural engineering technology, engineering cost management, building intelligent engineering technology, and prefabricated construction engineering technology. This group acts as a central platform for nurturing talents that are in short supply across the industry. Its primary objective is to dismantle the barriers of single-major training and cultivate interdisciplinary talents equipped with a robust foundation in civil engineering and digital intelligence technical competence. Industry-education integration is the fundamental pathway for vocational education to align with industrial demands and achieve a harmonious supply-demand match. However, the current state of industry-education integration within the intelligent construction specialty group is beset by several shortcomings. School-enterprise cooperation often remains superficial, limited to agreement signing, guest lectures, and short-term internships. Enterprises frequently lack intrinsic motivation to participate actively in talent cultivation, leading to a persistent dilemma of enthusiastic educational institutions facing indifferent enterprises. Furthermore, curriculum updates lag behind the rapid technological iterations of new quality productivity, resulting in a severe shortage of cutting-edge content such as digital twins, City Information Model platform applications, and construction robot operations. This disconnect from practical post requirements is exacerbated by training bases that prioritize hardware construction over practical application, lacking authentic frontline industrial scenarios and significantly compromising training effectiveness. Additionally, talent evaluation tends to overemphasize theoretical assessment, failing to objectively measure students' practical skills and industrial adaptability.

New quality productivity is characterized by technological innovation, data-driven development, and efficient collaboration, with its core connotation aligning closely with the reform goals of industry-education integration for the intelligent construction specialty group. Leveraging the empowerment of new quality productivity to dismantle technical, resource, and institutional barriers between industry and education, and to construct a targeted industry-education integration pathway that meets industrial development needs, is not only a practical solution to current talent training dilemmas but also an inevitable requirement for vocational education to precisely serve the high-quality development of the construction industry. Based on the intrinsic features of new quality productivity and the practical demands of the intelligent construction industry, this study clarifies industrial post competency standards, establishes a systematic industry-education integration pathway, and verifies its implementation effects through empirical analysis. It aims to provide theoretical support and operable practical plans for enhancing the quality and efficiency of industry-education integration in intelligent construction specialty groups. By doing so, the study seeks to bridge the gap between educational outcomes and industry requirements, ensuring that graduates are well-prepared to meet the challenges of a rapidly evolving construction sector. This alignment is crucial for fostering a workforce that is not only technically proficient but also adaptable to the dynamic nature of modern construction practices.

2. Core Concepts and Coupling Logic

2.1. Definition of Core Concepts

2.1.1. New Quality Productivity

New quality productivity represents a sophisticated evolution in productivity paradigms, moving away from the conventional model of extensive economic growth. This transformation is driven by groundbreaking technological advancements, innovative

reallocation of production resources, and comprehensive industrial transformation and upgrading. It is characterized by four fundamental attributes: it is led by innovation, enabled by digital technologies, focused on low-carbon and environmentally friendly practices, and emphasizes efficient collaboration. Leveraging state-of-the-art information technologies such as artificial intelligence, big data analytics, and the Internet of Things, this concept aims to achieve high-quality development. It propels industries towards more advanced, intelligent, and sustainable transformations. In the context of the construction industry, new quality productivity is prominently reflected in novel business models like intelligent construction, prefabricated construction, and eco-friendly buildings. It also involves large-scale, scenario-based applications of cutting-edge technologies, including Building Information Modeling (BIM), Construction Information Modeling (CIM), construction robotics, and digital twins. The primary objective is to achieve digital management and intelligent enhancement throughout the entire lifecycle of construction projects, ensuring efficiency and sustainability [1, 2].

2.1.2. Intelligent Construction Specialty Group

Driven by the ongoing digital transformation within the construction industry, the intelligent construction specialty group represents a cohesive cluster of interconnected disciplines. These disciplines seamlessly integrate architectural engineering, advanced intelligent technology, engineering cost management, and prefabricated construction techniques. The group adheres to a progressive development philosophy that emphasizes civil engineering as its foundational element, intelligence as its core focus, and the integration of industry and education as its operational chain. This approach transcends the limitations of traditional single-major training programs by encompassing the entire spectrum of architectural design, construction processes, operational maintenance, and cost accounting. The primary objective is to cultivate a new generation of technical and skilled professionals who possess comprehensive capabilities in engineering design, construction management, intelligent operational maintenance, and data application. These professionals are equipped to meet the diverse demands of positions across the entire intelligent construction industrial chain, thereby enhancing their adaptability and effectiveness in a rapidly evolving industry landscape [3–5].

2.1.3. Industry-Education Integration

Industry-education integration represents an educational model that intricately connects vocational education with the broader scope of industrial development. The fundamental essence of this model is to foster a seamless connection among the education chain, talent chain, industrial chain, and innovation chain. By facilitating two-way coordination between educational institutions and enterprises, it enables resource sharing and leverages complementary advantages. This approach ensures that the cultivation of talent is in perfect harmony with the evolving demands of industries, effectively addressing the historical disconnect between vocational education and industrial development. Furthermore, it resolves the mismatch between the supply of skilled individuals and the specific demands of job positions. As a result, industry-education integration emerges as a pivotal pathway for enhancing the quality and efficiency of vocational education, thereby supporting and driving forward industrial advancement [6].

2.2. *Coupling Logic Between New Quality Productivity and Industry-Education Integration of the Intelligent Construction Specialty Group*

New quality productivity and the integration of industry and education within the intelligent construction specialty group are interconnected systems that engage in a mutually supportive and coordinated development relationship. On one side, new quality productivity offers essential directional guidance, technical support, and resource security for the integration of industry and education. It establishes the core competency requirements necessary for intelligent construction talents, thereby urging the specialty group to dynamically refine the curriculum system, enhance training equipment, and

innovate educational models. This ensures that talent cultivation remains aligned with the ongoing technological advancements in the industry. Conversely, the integration of industry and education within the intelligent construction specialty group provides crucial talent support, a fertile ground for innovation, and practical platforms for the realization of new quality productivity. Through collaborative educational efforts between schools and enterprises, it consistently supplies technical and skilled talents that are specifically tailored to meet industrial demands. This process facilitates the application and dissemination of new technologies and techniques within the construction industry, thereby accelerating the digital transformation of the sector. The coupling points between these two systems are concentrated on four key dimensions: technical adaptability, talent adaptability, resource adaptability, and institutional adaptability. These dimensions establish a robust theoretical foundation for the future development of pathways for industry-education integration [7].

3. Analysis of Pain Points in Industry-Education Integration of the Intelligent Construction Specialty Group Against the Background of New Quality Productivity

This study employs a comprehensive mixed research methodology that integrates a literature review, on-campus field investigations, and in-depth interviews with enterprises. The research focuses on more than 20 higher vocational colleges that offer programs in intelligent construction specialty groups, as well as over 30 construction enterprises, which include central state-owned enterprises, local leading enterprises, and specialized and sophisticated enterprises within China. By aligning with the development requirements of new quality productivity and considering industrial feedback, the study identifies and summarizes four core pain points currently affecting the integration of industry and education. These pain points highlight the challenges and opportunities present in the collaboration between educational institutions and the construction industry, emphasizing the need for a more cohesive and effective partnership to enhance the quality and relevance of vocational training in this field.

The issue of superficial school-enterprise coordination mechanisms and the unbalanced distribution of rights and responsibilities among stakeholders is a significant concern. This imbalance often results in ineffective collaboration, where the roles and contributions of each party are not clearly defined or mutually beneficial.

Currently, the majority of school-enterprise collaborations are initiated and driven by educational institutions, with enterprises showing a lack of intrinsic motivation to actively engage in the process of talent cultivation. This results in a prevalent imbalance characterized by enthusiastic educational institutions and indifferent enterprises. Most collaborations remain at a superficial level, limited to signing agreements, conducting industrial lectures, and organizing short-term internships. Enterprises, concerned about production schedules, cost control, and liability risks, are hesitant to deeply involve themselves in crucial aspects such as the formulation of talent training programs, development of core curricula, and implementation of practical teaching. The division of rights and responsibilities among government bodies, educational institutions, and enterprises remains unclear, lacking a long-term coordination mechanism that features benefit sharing and risk sharing. This vagueness makes it challenging to establish a virtuous cycle of mutual empowerment and win-win cooperation between educational institutions and enterprises, thereby hindering the potential for meaningful collaboration [8].

The curriculum system currently in place is outdated and rigid, lacking the necessary technical adaptability to meet modern industry demands. This rigidity poses a significant barrier to the effective integration of new technologies and methodologies into educational programs.

The existing curriculum system predominantly relies on traditional civil engineering content as its core framework, with a lengthy update cycle that fails to incorporate cutting-edge technologies related to new quality productivity in a timely manner. Essential courses, such as those covering digital twin technology, CIM platform operation, AI-based

construction management, and construction robot operation, are either absent or outdated, leading to a significant disconnect from the latest industrial applications. There is a notable misalignment between curriculum design and industrial post standards, with a clear separation between job requirements and course content. The integration of vocational skill level certificates in the field of intelligent construction into daily teaching is insufficient, leaving students with overly theoretical skills that do not meet the practical operational requirements of enterprises for intelligent construction and digital management [9].

The misalignment between virtual and real training scenarios, coupled with insufficient resource supply, presents a significant challenge to effective training.

College training bases are predominantly equipped with traditional construction equipment, facing a severe shortage of core intelligent construction training facilities that align with real industrial scenarios. The investment in hardware fails to keep pace with technological advancements. Although some colleges have developed virtual simulation training platforms, the content of these trainings is often oversimplified and does not accurately reflect the actual construction processes, technical standards, and management requirements of enterprise engineering projects, rendering practical skill training ineffective. Most off-campus training bases exist only nominally, as enterprises typically offer only observational positions, preventing students from engaging in core business activities such as intelligent construction and digital management. This significantly undermines the effectiveness of training programs [10].

The evaluation mechanism for talent cultivation is predominantly single and one-sided, lacking effective measures for assessing outcomes.

The current evaluation of talent cultivation is heavily centered on theoretical examinations and academic performance within colleges, displaying a clear bias towards valuing theoretical knowledge over practical skills and scores over actual ability. The evaluation process is singular, conducted solely by college educators, and excludes diverse evaluative perspectives such as those from enterprises, industry experts, and third-party evaluators. The content of the evaluation fails to encompass key indicators, including students' practical skills, industrial adaptability, certificate acquisition rates, and employment quality. There is an absence of a closed-loop evaluation and dynamic optimization mechanism for assessing the effectiveness of industry-education integration, making it impossible to accurately measure the quality of talent cultivation and its adaptability to industry needs. This deficiency hinders the targeted optimization of talent training programs, limiting their potential to produce graduates who are well-prepared for the demands of the modern workforce [11, 12].

4. Construction of a Four-Dimensional Pathway for Industry-Education Integration of the Intelligent Construction Specialty Group Empowered by New Quality Productivity

Addressing the previously mentioned challenges in the integration of industry and education, this study develops a comprehensive four-dimensional pathway. This pathway is grounded in the essential attributes of new quality productivity, alongside the developmental principles of the intelligent construction specialty group and the demands of industrial positions. The proposed pathway includes "government-school-enterprise coordination, post-course-competition-certificate integration, virtual-real scenario linkage, and diversified closed-loop evaluation." By implementing this approach, barriers across various stages are dismantled, facilitating a seamless and comprehensive integration of industry and education. This integration is directed towards achieving a full-chain, in-depth, and sustainable development, ensuring that all stakeholders benefit from a cohesive and collaborative framework [13].

4.1. Dimension 1: Government-School-Enterprise Coordination to Establish a Long-Term Education Mechanism

The establishment of a tripartite collaborative education platform, involving the government as the guiding force, colleges as the primary entities, and enterprises as the central participants, is essential for clarifying the boundaries of rights and responsibilities. This approach aims to enhance the benefit distribution mechanism, thereby addressing the prevalent issue of enthusiastic educational institutions facing indifferent enterprises in cooperative efforts. At the governmental level, specific support policies are implemented to provide financial subsidies and tax incentives that encourage school-enterprise cooperation. These policies also facilitate the creation of regional platforms that connect industry and education, ensuring the integration of high-quality industrial resources and standardizing the processes involved in school-enterprise collaborations. From the perspective of colleges, there is a proactive effort to establish connections with leading construction enterprises. This is achieved by forming an industry-education integration council, which invites enterprise experts to engage deeply in the development of specialties, management of teaching, and design of curricula. Regular seminars between schools and enterprises are also organized to foster collaboration. On the enterprise side, full participation in talent cultivation is promoted by assigning technical experts as mentors, offering training resources, specifying job requirements, and providing internship and employment opportunities. Enterprises also play a role in teaching evaluations. Ultimately, this coordinated effort results in a long-term mechanism characterized by government guidance, college leadership, enterprise participation, and a multi-party win-win situation.

4.2. Dimension 2: Post-Course-Competition-Certificate Integration to Optimize the Dynamic Curriculum System

In alignment with the evolving standards of intelligent construction, particularly under the influence of new quality productivity paradigms, this study meticulously identifies and organizes the essential competencies required for pivotal roles such as construction technicians, cost engineers, and personnel involved in intelligent operation and maintenance. The integration of post skills, vocational competition content, and certificate assessment criteria into the curriculum system is executed with precision, ensuring a seamless connection between post-course requirements, comprehensive course-competition integration, and a cohesive course-certificate framework. Initially, courses that no longer meet the demands of the industry are removed, making way for innovative courses that include digital twin technology, CIM platform applications, construction robot operations, and intelligent construction management, thereby revitalizing the curriculum. Furthermore, teaching materials are developed in collaboration with enterprise technical experts, adopting a loose-leaf and project-based approach. These materials incorporate real enterprise projects and the latest technologies and techniques, ensuring that teaching content remains in sync with industrial advancements. Additionally, there is a precise alignment with vocational skill level certificates specific to the intelligent construction sector. Certificate assessment criteria are systematically broken down and integrated into daily teaching practices, facilitating modular teaching and training. This approach culminates in an integrated model of "learning-training-assessment," which effectively bridges the gap between education and industry requirements.

4.3. Dimension 3: Virtual-Real Scenario Linkage to Upgrade Practical Teaching Carriers

A comprehensive training system, integrating virtual simulation, on-campus training, and enterprise practice, is established to create a cohesive teaching model that merges virtual and real-world experiences with theoretical and practical learning. This approach addresses the limitations of traditional single-mode training systems. On the university campus, an advanced construction training center is developed, featuring state-of-the-art BIM modeling tools, construction robots, and intelligent measuring devices. These are complemented by a digital twin virtual simulation platform designed to replicate authentic industrial environments, such as smart construction sites, prefabricated building processes, and digital cost management. This setup allows

students to engage in virtual practical training initially. Beyond the campus, partnerships with enterprises facilitate the creation of on-site training bases. These bases select exemplary engineering projects as training platforms, where students participate in practical activities like intelligent construction and digital management within actual enterprise settings. The implementation of a "four-classroom" linkage model further enhances this system by integrating foundational theoretical instruction, virtual classrooms for skill development, on-campus training for practical application, and enterprise practice for comprehensive literacy enhancement.

4.4. Dimension 4: Diversified Closed-Loop Evaluation to Improve the Effectiveness Assessment System

A comprehensive and diversified evaluation system is established, integrating assessments from colleges, enterprises, industries, and third-party evaluators. This system is designed to overcome the constraints of evaluations conducted solely by educational institutions, thereby enabling a holistic and continuous assessment process. The evaluation involves various stakeholders, including full-time college educators, technical mentors from enterprises, seasoned industry experts, and independent evaluation bodies, all collaborating to provide a multifaceted assessment. The scope of evaluation encompasses a wide range of areas such as theoretical knowledge, practical skills, certification achievements, project-based learning, professional conduct, and employment outcomes. This broad approach ensures a thorough evaluation of students' overall capabilities and the effectiveness of their education. Furthermore, a feedback mechanism is implemented to systematically review and analyze evaluation data. This process helps in identifying gaps in talent development, allowing for the targeted enhancement of curriculum design, training content, and educational methodologies. Consequently, a dynamic closed-loop management system of evaluation, feedback, optimization, and improvement is formed, ensuring continuous advancement in educational quality and effectiveness.

5. Empirical Research

5.1. Empirical Objects and Research Design

This study focuses on full-time students from the 2022 and 2023 cohorts within the intelligent construction specialty group at a higher vocational college located in East China. The research encompasses a total sample size of 426 students. Specifically, 218 students from the 2023 cohort are designated as the experimental group. These students receive education through the innovative four-dimensional industry-education integration pathway developed in this study. In contrast, the 208 students from the 2022 cohort form the control group, following the college's traditional industry-education integration model. The research cycle extends over two academic years, thoroughly covering all stages of core professional course learning, practical training, and post-internship experiences. The effectiveness of the four-dimensional pathway is rigorously evaluated using a variety of methods. These include comprehensive questionnaire surveys, detailed comparisons of academic performance, feedback from enterprises regarding employment, statistical analysis of employment data, and skill assessments. This multifaceted approach ensures a robust verification of the pathway's impact on educational outcomes and employability.

5.2. Selection of Empirical Indicators

In alignment with the objectives for cultivating talent within the intelligent construction specialty group, the evaluation requirements for industry-education integration, and the demands of enterprise positions, a comprehensive selection of five core indicators has been made. These indicators are chosen based on their adherence to the principles of scientificity, quantifiability, and comparability. The selected indicators include the average scores of core professional courses, which reflect the foundational knowledge acquired by students, and the skill certificate acquisition rate, which

demonstrates the practical competencies gained. Additionally, the practical training assessment pass rate is considered, highlighting the effectiveness of hands-on learning experiences. The enterprise satisfaction score provides insight into how well the educational outcomes meet industry expectations, while the major-related employment rate indicates the success of graduates in securing relevant positions. The effectiveness of the industry-education integration pathway is measured objectively through a comparative analysis between different groups, ensuring that the empirical results are both authentic and reliable (As shown in Table 1).

Table 1. Comparison of Evaluation Indicators Between Experimental and Control Groups

Evaluation Indicators	Experimental Group (Four-Dimensional Pathway)	Control Group (Traditional Mode)	Increase Margin
Average Scores of Core Professional Courses	85.6 points	76.2 points	9.4 points
Skill Certificate Acquisition Rate	92.3%	68.7%	23.6%
Practical Training Assessment Pass Rate	96.8%	81.5%	15.3%
Enterprise Satisfaction Score	91.2 points	78.3 points	12.9 points
Major-Related Employment Rate	89.7%	65.4%	24.3%

5.3. Empirical Results and Analysis

The empirical results indicate that all core indicators of the experimental group are significantly superior to those of the control group. The major-related employment rate records the largest increase of 24.3%, followed by the skill certificate acquisition rate with a 23.6% rise; both the practical training assessment pass rate and enterprise satisfaction score achieve double-digit growth, and the average score of core professional courses increases by 9.4 points. According to on-site enterprise research feedback, students in the experimental group not only master solid theoretical knowledge but also possess proficient digital intelligence practical skills, with quick post adaptation and high job matching degree. Their professional literacy and teamwork capability have been highly recognized by enterprises, fully verifying that the four-dimensional industry-education integration pathway constructed in this study features strong feasibility and effectiveness, and can effectively address the current pain points in industry-education integration. This suggests that the approach not only enhances individual competencies but also aligns educational outcomes with industry needs, thereby fostering a more dynamic and responsive workforce. The implications of these findings are profound, as they highlight the potential for such integrative models to be adapted across various educational and industrial contexts, potentially revolutionizing how educational institutions and industries collaborate.

6. Conclusions and Prospects

New quality productivity injects new impetus and clarifies the development direction for the reform of industry-education integration of the intelligent construction specialty group. To resolve the existing dilemmas in industry-education integration, it is essential to adhere to the core requirements of innovation-driven and digital-enabled development, abandon superficial school-enterprise cooperation models, and build a

systematic and in-depth collaborative education pathway. The four-dimensional system established in this study—featuring government-school-enterprise coordination, post-course-competition-certificate integration, virtual-real scenario linkage, and diversified closed-loop evaluation—precisely tackles core problems including loose school-enterprise collaboration, outdated curriculum content, misaligned training scenarios, and a single evaluation mechanism, realizing the deep integration of the education chain and industrial chain. Empirical results confirm that this pathway can effectively improve talent cultivation quality and industrial adaptability, providing a replicable and promotable practical reference for advancing the high-quality development of industry-education integration in intelligent construction specialty groups across similar colleges and universities. The broader implications of this study suggest that such a model could serve as a blueprint for other sectors seeking to enhance their educational frameworks. However, potential limitations include the need for ongoing adaptation to rapidly changing technological landscapes and the necessity for continuous stakeholder engagement to maintain alignment with industry advancements. Future research should focus on longitudinal studies to assess the long-term impacts of this integration model and explore its applicability in diverse educational and industrial settings, ensuring that it remains relevant and effective in meeting the evolving demands of the workforce.

Future Research Directions: Although this study has verified the feasibility and effectiveness of the four-dimensional pathway through empirical research on regional higher vocational colleges, certain limitations remain: the research scope is confined to local colleges, and the exploration of in-depth school-enterprise cooperation models needs to be strengthened. Future research can be expanded in three aspects: first, broaden the empirical scope to include colleges in central and western regions and undergraduate-level vocational institutions, enhancing the universality of the research conclusions; second, deepen the government-school-enterprise coordination mechanism and explore advanced cooperation models such as mixed-ownership industrial colleges, customized talent classes, and school-enterprise joint R&D platforms; third, keep pace with the iteration of emerging technologies including artificial intelligence and big data, dynamically optimize the curriculum system and training scenarios, promote the synchronous development of industry-education integration and new quality productivity, and cultivate more high-caliber technical and skilled talents to support the high-quality development of the construction industry.

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