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Research on the Talent Development Model for Smart Construction in Vocational Colleges

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Abstract: In the context of the new era, human society is ushering in the fourth wave of the industrial revolution, which will have profound implications for various industries, especially the construction industry. The upgrading of the construction industry is imperative to adapt to new technologies and trends. In response to the requirements of this era, smart construction is emerging as the way forward. Major universities are responding to national policies by establishing programs in smart construction to meet the growing demand for talent. This is both a response to the demands of the times and strong support for the future development of the construction industry. Smart construction training programs at universities are crucial, and they need to integrate students with new technologies and trends in education to cultivate forward-thinking professionals with practical skills. The core technologies of smart construction include BIM technology, 3D printing, smart machinery, and artificial intelligence. These technologies will redefine the design, construction, and maintenance management of construction projects. For instance, BIM technology can provide comprehensive project information and collaboration, 3D printing can enable efficient construction, smart machinery can autonomously perform tasks, and artificial intelligence can empower construction projects with greater decision-making capabilities. For universities, nurturing professionals in smart construction requires continuously updating educational curricula and providing practical opportunities to ensure that students can master and apply these emerging technologies. This will help produce graduates with innovative thinking and problem-solving abilities, providing strong support for the future development of the smart construction field. This trend will also promote a more intelligent, efficient, and sustainable development of the construction industry.

1. Introduction

With the rapid development of our country's economy, the construction industry has made significant progress, with numerous world-class projects completed and put into use. As China's economic development enters a new normal, industrial upgrading has gradually become a crucial lever for our economic growth. In recent years, as computer information technology has advanced rapidly, the concept of the New Engineering Discipline has been proposed, incorporating artificial intelligence into traditional civil engineering. As China enters a new stage of high-quality economic development, smart construction has become an inevitable trend in the construction industry's development and a significant component of industrial transformation and upgrading [1]. Smart

construction is an interdisciplinary field that combines advanced technologies such as BIM technology, computer big data, and artificial intelligence, playing a leading role in the new wave of the construction industry revolution [2]. Various countries around the world have based their national conditions and gradually established industrial strategies and talent development systems centered around smart construction. Leading developed countries worldwide require the application of BIM technology in construction projects, and they have also established corresponding technical standards and allocated substantial funds for 3D printing, artificial intelligence, and other related areas [3].

In 2017, Tongji University successfully introduced the Smart Construction program, followed by the approvals of six more institutions, including North China University of Technology and North China University of Technology, bringing the total to 64 institutions offering related programs. However, as a newly established field, each institution has its unique characteristics. Still, the challenge for these institutions offering smart construction programs lies in how closely they can align their curriculum and development plans with the Fourth Industrial Revolution, and adapt to the demands of society. To address this challenge, universities must closely monitor the latest developments in the smart construction field and establish strong ties with industry partners to ensure that their course content aligns with industry requirements. Furthermore, universities should encourage students to actively participate in real-world projects, providing them with practical opportunities to apply their theoretical knowledge to actual work. This close integration of theory and practice in education will help cultivate forward-thinking professionals with practical skills in the field of smart construction, providing strong support for the future development of the construction industry. This not only helps meet domestic demands but also aims to establish China's reputation in the international arena for smart construction.

2. Development of Smart Construction Training Programs

The development of smart construction training programs is a critical step in nurturing future talent for the construction industry. This program should not only meet the requirements of national engineering education accreditation but, more importantly, should encourage the transformation of traditional civil engineering disciplines into the realm of smart construction. To achieve this goal, the training program must be forward-thinking and comprehensive, breaking down the barriers between disciplines and integrating knowledge from various fields into a unified educational framework.

Within the smart construction training program, core civil engineering courses still hold a significant place. However, they need to be integrated with advanced information technologies, such as the Internet of Things, big data, and Building Information Modelling (BIM) technology. This integration allows students to acquire the necessary skills across all phases of construction projects, from design to production, construction, and full-cycle operation and maintenance management. This comprehensive educational approach helps students understand the entire construction lifecycle, fostering interdisciplinary capabilities to meet the demands of the future smart construction field.

Furthermore, the training program should encompass principles of mechanical and control engineering as well as knowledge of engineering management to provide a broader background, enabling students to gain a comprehensive understanding of the complexities of the smart construction domain. The deep integration of these knowledge areas will help nurture students with innovative thinking and problem-solving abilities, making them leaders in the future of the smart construction field and driving the construction industry towards a more intelligent, efficient, and sustainable direction.

2.1. Breaking down Disciplinary Barriers

Currently, higher education in China is categorized into 14 academic disciplines, with 113 primary

disciplines within them. In 2020, a 14th category, "Interdisciplinary Studies," was added, signalling a new direction for universities and the education sector. However, with the rise of the Fourth Industrial Revolution, the convergence and intersection of different disciplines have become an important trend. Traditional civil engineering programs are no longer sufficient to meet the complex demands of modern society. Therefore, it is necessary to break the traditional boundaries of civil engineering disciplines and reconsider core courses and specialization directions. The field of smart construction, while imparting knowledge related to civil engineering to students, emphasizes guiding them to learn new technologies and new ways of thinking about construction informatization and intelligence. This requires educational institutions not only to teach technical knowledge but also to inspire students' enthusiasm for learning and cultivate a strong belief so that they can continuously adapt to and lead technological developments.

In this context, a "Five-in-One" training model has been established (see Figure 1), which deeply integrates multiple disciplinary areas, including computer science and technology, mechanical engineering, electrical engineering, management science and engineering, and civil engineering. This integration helps cultivate well-rounded professionals who possess a broad knowledge and skills in the field of smart construction. Additionally, it allows for the development of distinctive training directions based on the characteristics of different institutions. This interdisciplinary educational approach will facilitate students in better understanding and applying emerging technologies, promoting innovative thinking and problem-solving abilities. Furthermore, it helps meet the demand for high-quality talents in society, providing robust support for the sustainable development of the smart construction industry. In the continuous process of breaking down disciplinary barriers, universities and educational institutions will play a crucial role in driving greater breakthroughs in the field of smart construction.

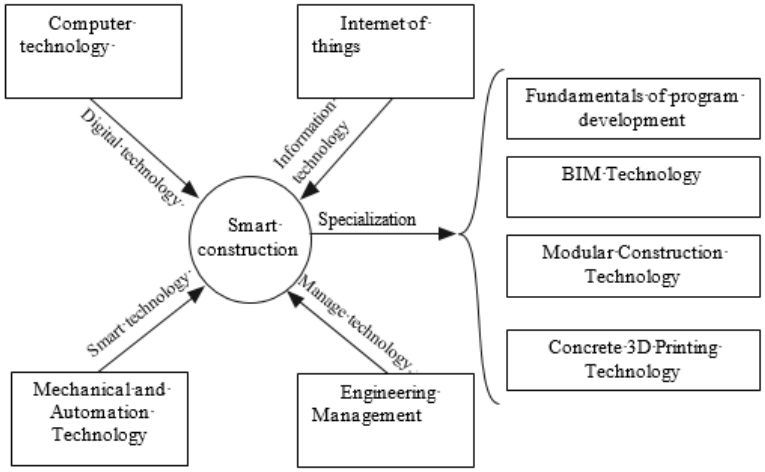

Figure 1: Education Model Diagram

2.2. Nurturing Creative Thinking in Students

Universities are considered sanctuaries for education, with their fundamental mission being the dissemination of specialized knowledge to enable students to adapt to the constantly changing and evolving society. However, in the context of the new wave of technological and industrial revolutions today, the essence of national competitiveness lies in the competition for innovation capabilities. Therefore, universities, under the backdrop of the New Engineering disciplines, must reconsider traditional teaching concepts and place a greater emphasis on nurturing students' innovation abilities. For students majoring in smart construction, it is only through possessing a high level of innovative awareness and capability that they can drive the transformation of the construction industry and

promote the overall industry's sustainable development [4].

How can the cultivation of innovation capabilities be integrated into the training programs for smart construction majors? First, this can be achieved by introducing innovative practical courses, such as adding courses on "Innovation, Entrepreneurship, and Individual Education" to the curriculum. Students can accumulate credits by participating in various competitions like the "National Structural Design Competition," "National BIM Graduation Design Competition," and the "National College Student Traffic Technology Competition." This not only helps foster students' innovative awareness but also enhances their innovation capabilities. Second, practical course experiments can be established, such as experiments in "Concrete 3D Printing Technology" and "Modular Construction Technology." These experiments not only improve students' hands-on skills but also subtly cultivate their innovative thinking. Through these practical courses and experiments, students will better understand and apply emerging technologies while also developing problem-solving and innovation skills. Therefore, universities should actively explore innovative educational methods to equip students in the field of smart construction with stronger innovative thinking and capabilities, injecting more vitality and innovation into the future of the construction industry. This will contribute to driving the entire industry towards a more intelligent, efficient, and sustainable direction.

3. Transformation of Training Approaches: From Traditional Construction to Smart Construction

In university education, the training direction for smart construction professionals is of paramount importance to ensure that students can comprehensively grasp the relevant knowledge and skills and meet the increasingly complex demands of the construction industry. To achieve this goal, it is necessary to integrate the application of new technologies, such as construction cases, into traditional civil engineering education. This involves introducing content from new engineering disciplines, including mechanical engineering, intelligent robotics technology, and artificial intelligence algorithms, to meet the knowledge requirements of the smart construction field.

In response to the challenges posed by the addition of new courses, universities can adopt a progressive training model. In the first two years of the smart construction program, students can receive comprehensive training, including fundamental knowledge in civil engineering, principles of mechanics and design, and basic computer science courses. This learning path helps students establish a solid foundation in civil engineering while preparing them for advanced specialization. In the third year, students have the flexibility to choose different specialization tracks based on their interests and career aspirations. These tracks include Smart Construction Design, Smart Construction Equipment, and Smart Construction Algorithms. This classification-based training allows students to delve deeper into various aspects of smart construction, focusing on smart design, equipment, as well as robotics and artificial intelligence algorithms. This progressive training approach ensures that students have a comprehensive civil engineering background while gaining in-depth expertise in the field of smart construction. It helps produce graduates with a wide range of skills, who will make significant contributions to the development and innovation in the smart construction industry. Additionally, this training model also helps students better understand their interests and career development directions, providing a solid foundation for future employment and research directions.

3.1. Smart Construction Design

In the field of smart construction design, a crucial task is addressing the issue of intelligent design within smart construction. Architectural Information Modelling (BIM) becomes a key element that disrupts traditional calculation, drawing, and construction methods, emphasizing the cultivation of

intelligent design concepts. University curricula should place a strong emphasis on developing students' capabilities in BIM technology and 3D printing technology.

BIM technology, or Building Information Modelling technology, digitally represents buildings, enabling precise management of the entire construction project lifecycle through digital model data. This technology helps engineering professionals correctly understand and efficiently handle architectural information [5]. In the United States, BIM technology has yielded over a 50% return on investment, and many major domestic enterprises in China are actively promoting its application. However, China is currently facing a shortage of BIM talent. While many universities offer BIM technology-related courses, most are elective courses with low student participation. Therefore, the smart construction design program focuses on developing students' BIM skills. The curriculum includes not only fundamental BIM modelling instruction but also practical training based on real engineering cases. Schools encourage students to actively participate in BIM competitions to stimulate their learning interest and ensure the application of their knowledge [6-7].

The smart construction design program also offers 3D printing courses, with a focus on teaching the principles and practical operation of 3D printing. Students learn about advanced materials suitable for printing, master relevant algorithms, and achieve basic printing programming. In these courses, students have the opportunity to experience the entire 3D printing process firsthand. Moreover, schools can actively promote collaboration with industry partners, inviting leading domestic 3D printing companies to participate in training and keeping track of the latest industry developments to ensure that students acquire the most up-to-date knowledge and skills. This comprehensive training approach helps ensure that students graduate with a competitive edge for successful employment in the field of smart construction design.

3.2. Smart Construction Equipment

The task in the field of smart construction equipment is to address the challenges related to intelligent construction, aiming for reduced labor, automation, and standardized construction processes. This specialization primarily focuses on intelligent machinery and smart construction robots based on mechanical automation[8]. Traditional construction sites involve complex interactions between on-site personnel and construction equipment, making precise management of construction relatively challenging [9]. However, intelligent robots can effectively address this issue. Given the complexity of construction sites, the development of intelligent robots is typically targeted at highly repetitive construction processes [10]. Intelligent construction platforms are comprehensive systems that integrate various operational scenarios, construction equipment, and construction processes, achieving automation in multiple stages through computer system control [11].

To meet the real needs of the construction industry, the Smart Construction Equipment specialization requires a deep understanding of mechanical engineering courses, particularly those related to civil engineering. Additionally, courses should emphasize the study of intelligent robot-related topics, enabling students to acquire the skills for operating and maintaining this intelligent equipment. The introduction of a doctoral advisor system within the classroom is intended to allow students early exposure to research content, guiding them to analyze the principles behind construction processes, and bridging theory with practice. This will provide a solid foundation for further research and development in robot-automated construction processes. Moreover, educators are encouraged to integrate their research findings into real-world engineering cases, introducing them as examples in the classroom. This way, students will have the opportunity to enhance their problem-solving abilities and foster innovative thinking through research exploration. This comprehensive education and training approach help ensure that graduates are competitive for practical work and research in the field of smart construction equipment [12]. Consequently, they will

be able to actively participate in and drive the modernization and smart development of the construction industry.

3.3. Smart Construction Algorithms

The key task in the field of smart construction algorithms is to address the issues of intelligent operation and maintenance management in smart construction. It focuses on applying artificial intelligence algorithms to build model frameworks for sensing, analyzing, and correcting the construction process, ultimately enhancing project management precision comprehensively, with the goal of reducing costs and increasing efficiency.

Today, artificial intelligence has seen rapid development in various fields, giving rise to numerous algorithms [13]. Globally, various industries are actively exploring how to integrate computer information technology with traditional industries to drive their upgrading and transformation. Although the construction industry has relatively lower levels of smart and information technology adoption, artificial intelligence holds promising applications in civil engineering [14]. In smart construction, artificial intelligence is primarily manifested through algorithm-based deep learning. For example, Liu Zhansheng and others have developed a framework for smart construction methods based on digital twin technology, combining the Internet of Things, Building Information Modeling (BIM), and finite element models [15].

As a result, the emphasis in the field of smart construction algorithms is on advancing research in deep learning. In education, we use the latest engineering cases as a starting point, guiding students to deepen their understanding of the integration of algorithms with civil engineering practice. Students explore how to apply deep learning algorithms to enhance the management efficiency, quality, and sustainability of construction projects. This will provide them with a solid foundation for their future career development, ensuring their success in the field of smart construction.

4. Conclusion

With the introduction of the national new infrastructure strategy, China's construction industry is rapidly evolving towards intelligence and informatization. To adapt to this new development landscape, smart construction will flourish in the future. In this context, universities should take on the crucial mission of nurturing smart construction talent and actively innovate their talent development models to meet the demands of the new era.

1) Regarding the curriculum system, it is essential to clearly emphasize key areas. This includes trimming outdated content from traditional civil engineering technology and enhancing the teaching of BIM technology and 3D printing technology to ensure the timely update of course content. Simultaneously, universities should actively transform research achievements into teaching resources, promoting the organic integration of research and teaching.

2) Existing curriculum barriers need to be broken down, introducing courses such as mechanical principles and design, intelligent robotics, artificial intelligence, and algorithms. By organically fusing these courses with civil engineering disciplines, students will come into contact with cutting-edge knowledge, kindling their interest and enhancing their ability to apply computer technology and artificial intelligence to address civil engineering challenges.

3) Striking the right balance between traditional and new courses is crucial. The talent development in smart construction should revolve around engineering construction, not merely a simple addition of traditional courses and mechanical and computer-related courses. It's necessary to add new technology-related courses on the foundation of students' existing knowledge in civil engineering, reasonably allocate hours, increase the theoretical learning proportion in traditional courses, and enhance the practical component in new technology-related courses.

4) Maintaining the principle of combining theory and practice is vital. In addition to theoretical learning, practical components need to be strengthened. This includes not only traditional on-site internships but also strengthening collaboration between universities and businesses, implementing the integration of industry, academia, and research. This approach enables students to genuinely immerse themselves in real work environments and better adapt to societal needs. This comprehensive educational approach will help cultivate smart construction professionals with cutting-edge knowledge and practical skills, contributing to the industry's continuous development.

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