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Comparative Analysis of Talent Cultivation Systems for Civil Engineering Majors in Higher and Vocational Colleges Based on Mathematical Models

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Abstract:
This paper aims to explore the logical relationship between talent cultivation objectives and curriculum system differences under the integrated cultivation system of higher vocational education and vocational schools, based on mathematical models. By comparing the talent cultivation standards and curriculum standards of civil engineering majors in vocational and higher vocational colleges in Chongqing, it is found that while both emphasize the cultivation of technically skilled talents, higher vocational colleges place more emphasis on developing high-quality technical skilled talents with strong sustainable development ability and industry adaptability. In terms of career orientation, both vocational and higher vocational colleges set corresponding vocational qualification certificates as development goals, but adjustments must be made in practice according to the characteristics of the profession and market demand. Vocational colleges focus more on the proficiency of basic skills, while higher vocational colleges add courses that align with industry development trends and the need for higher-level engineering personnel, such as modular construction, 3D scanning, and digital construction technologies, reflecting the different levels of educational objectives and focuses. Moreover, the teaching content of core courses also shows hierarchical differences, with higher vocational colleges expanding both depth and breadth to meet the needs of more advanced career development.

Keywords: civil engineering; vocational and higher vocational education; talent cultivation system; mathematical models; comparative analysis; curriculum system

INTRODUCTION

In order to accurately align with the strategic needs of integrated talent cultivation in vocational and higher vocational education, the primary task is to clearly define and outline the inherent connections and progressive logical relationships between the talent cultivation systems of vocational and higher vocational colleges [1,2]. To this end, we conducted an in-depth study of civil engineering majors in vocational and higher vocational colleges in Chongqing, extensively collecting specific data on talent cultivation standards from key vocational and higher vocational institutions in the region. We then established mathematical models to conduct comparative analysis, calculating the data differences between vocational and higher vocational education and carefully comparing the curriculum standards of both levels of vocational education. This approach aims to fully capture the subtle differences in educational content and hierarchical divisions.

In traditional perceptions, vocational education is often viewed as a cradle for technical workers. However, with the increasing prominence of industries such as construction, the traditional model of training technical workers has proven inadequate to meet the diversified needs of the market, especially in the field of civil engineering. This challenge is particularly significant. Given the increasing difficulty in recruitment and changes in industry demands, many vocational and higher vocational institutions in civil engineering have, quite independently, raised their training goals to the level of technical personnel, striving for a deeper integration of professional skills and theoretical knowledge. While this trend has promoted the sharing and optimization of educational resources, it has also posed higher requirements for the differentiated development of vocational and higher vocational education. Therefore, our comparative analysis not only aims to clarify the convergence of their current positioning but also seeks to explore how to refine their respective cultivation characteristics and focuses under a unified goal, ensuring effective continuity and scientific progression in talent cultivation between vocational and higher vocational education.

COMPARISON OF TALENT CULTIVATION OBJECTIVES, CAREER ORIENTATION, AND STANDARDS BETWEEN VOCATIONAL AND HIGHER VOCATIONAL EDUCATION

Analysis of Cultivation Objectives

By analyzing the talent cultivation programs of five vocational colleges and five higher vocational colleges offering civil engineering majors in Chongqing, we summarized the cultivation objectives into a comparison scheme as shown in Table 1. From this comparison, it is evident that the vocational education aims to cultivate "high-quality laborers and technically skilled talents." The term "laborer" is a legal concept referring to individuals with the ability to work, engaging in labor to receive legal compensation. Laborers can be intellectual or manual workers. The use of "laborers" here seems to intentionally avoid the idea of manual laborers, which implies a potential avoidance of becoming construction workers. The second part, "technically skilled talents," should be more accurately stated [3].

For higher vocational education, the cultivated talents are "high-quality technical skilled professionals capable of engaging in construction technology and construction activity management." The term "high-quality" raises the question of what "high" specifically refers to. From the subsequent curriculum system, it can be interpreted more appropriately as "having stronger sustainable development ability and industry adaptability" [4].

Table 1. Comparison of cultivation objectives between vocational and higher vocational education

Item	Vocational Education	Higher Vocational Education	Remarks
Cultivation Objectives	This major adheres to the concept of integrating ideological and political education into the curriculum, fulfilling the fundamental mission of fostering virtue and moral character. It aims to cultivate professional talents for Chongqing and the western region, focusing on the construction, supervision, and consulting industries. Graduates are expected to possess strong job-specific skills, good professional qualities, vocational skills, and self-learning capabilities; they are equipped with knowledge and skills in engineering construction and management, supervision, etc., and meet the requirements of professional positions in production, technology, management, and services in the frontline of the construction industry. Graduates are well-rounded individuals with strong moral, intellectual, physical, aesthetic, and labor qualities who are also high-quality workers and technically skilled talents.	This major cultivates professionals who uphold the core values of socialism, develop morally, intellectually, physically, aesthetically, and through labor, and possess a certain level of scientific and cultural knowledge, good humanistic qualities, professional ethics, and an innovative mindset. Graduates are expected to embody the craftsmanship spirit of striving for excellence, possess strong employability, entrepreneurial abilities, and sustainable development capabilities. They will master the professional knowledge, technical skills, and competencies needed for building engineering and management professions, such as architectural engineering technicians and management technicians. Graduates are expected to work as high-quality technical professionals capable of engaging in construction technology and management activities.	

Analysis of Career Orientation

Based on the talent cultivation programs of the five vocational and five higher vocational colleges mentioned earlier, a comparative scheme for career orientation at vocational and higher vocational levels is summarized in Table 2 [5,6]. The career orientation for vocational education is described with precision; however, according to the current professional standards for on-site construction personnel in the construction industry, vocational school graduates must have at least three years of on-site professional practice experience. This means that upon graduation, vocational students cannot meet these goals, which can only serve as their future career development objectives.

Table 2. Comparison of career orientation between vocational and higher vocational education

Item	Vocational Education	Higher Vocational Education	Remarks
Career Orientation	Qualification certificates: Site Foreman, Surveyor, Document Clerk, Supervisor, Safety Officer, Draftsman, BIM Modeling Certification	National Professional Qualification Certificates: Constructor, Certified Cost Engineer Vocational Skill Certificates: - Construction Drawing Recognition - Building Information Modeling (BIM) - Implementation and Management of Construction Techniques - Prefabricated Construction Component Manufacturing and Installation Other certificates: Site Foreman, Quality Inspector, Safety Officer, Document Clerk	

The description of career orientation for higher vocational education also carries an aspirational tone. For example, national professional qualification certificates, such as Constructor and Certified Cost Engineer, cannot be obtained at the time of graduation by higher vocational students and therefore can only serve as future career development goals.

Regarding vocational skill certificates, these certificates currently lack market demand in the industry and should not be considered as professional goals. Instead, they can be treated as skill objectives during the training process but are not suitable for inclusion as career orientation goals in professional standards since they do not correspond to specific professions [7].

For higher vocational students, the most accurate and achievable goal at the time of graduation is obtaining on-site construction personnel certificates, such as Site Foreman, Quality Inspector, and Document Clerk. According to the professional standards for on-site construction personnel in the construction field, higher vocational students can take these certification exams after completing one year of professional practice, which includes on-campus training and internship periods. Therefore, the career orientation goal for higher vocational students can be directly defined as on-site construction personnel in the construction field.

Cultivation Standards

For cultivation standards, both vocational and higher vocational education primarily describe attributes in terms of literacy, knowledge, and skills. There are no significant differences, except for minor hierarchical distinctions. Therefore, no detailed analysis will be provided.

COMPARATIVE ANALYSIS OF CURRICULUM SYSTEMS IN VOCATIONAL AND HIGHER VOCATIONAL EDUCATION

Comparison of Course Offerings in Vocational and Higher Vocational Education

The curriculum system is the core content of the talent cultivation program and directly determines the effectiveness of talent cultivation. In this section, we conducted a comprehensive review of the courses offered by the five vocational colleges and five higher vocational colleges identified earlier. The resulting comparison of curriculum systems is shown in Table 3 [8-10].

Table 3. Comparison of curriculum systems between vocational and higher vocational education

Vocational Education			Higher Vocational Education			Remark
Course Category	Course Name	Hours	Course Category	Course Name	Hours	
Public Basic Courses		1062	Public Basic Courses		1050	
Professional Core Courses	Architectural Drawing and Interpretation	72	Engineering Drawing	Professional Basic Courses	36	
			Engineering Interpretation (including practical training)		54	
			Building Mechanics		72	
			Building Structures and Calculations (including drawing interpretation)		72	
	Building Construction	72	Building Structures and Function Analysis		36	
			Building Function and Construction Practical Training		45	
			Engineering Geology		36	
			Professional Basic Courses Subtotal	Professional Directional Courses	306	
	Building Materials	72	Building Materials and Testing Techniques		54	
			Building Material Testing Practical Training		18	
	Building CAD (including Tianzheng)	144	CAD-Assisted Design		36	
	Construction Technology	216	Construction Technology		72	
			Construction Skill Practical Training (including virtual construction practical training)		45	
	Construction Organization and Management	72	Construction Organization and Management		54	
			Construction Organization and Management Practical Training		18	
	Construction Safety, Energy Conservation, and Environmental Protection	72				
	BIM Technology Application	108	BIM Modeling		36	

		Building Engineering Surveying	90	Engineering Surveying		54	
				Engineering Surveying Practical Training		36	
				Prefabricated Concrete Structure Construction Techniques		45	
				Installation Drawing Interpretation and Construction Techniques		54	
		Professional Core Courses Subtotal	918				
Professional Directional Courses	Construction Techniques and Safety Management	Rebar Processing and Craftsmanship	72				
		Construction Safety Management	108	Construction Safety Management		36	
		Construction Measurement and Pricing	72	Building Construction Measurement and Pricing		36	
				BIM Costing Software Application Practical Training		18	
		Professional Directional Courses Subtotal	252	Professional Directional Courses Subtotal		1311	
Professional Elective Courses		Craftsmanship and Technical Operations	72		Professional Extension Courses		
		Document Archiving and Organization	72	Engineering Acceptance and Documentation Management Practical Training		36	
		Building Engineering Quality Inspection	72				
		ubtotal	216				
Professional Internship		Construction Drawing Interpretation Comprehensive Training	90				
				3D Scanning and Digital Construction Techniques		36	
		Comprehensive Training in Building Engineering Surveying	72	Engineering Surveying Practical Training		36	
				Prefabricated Component Deepening Design Techniques		36	
		BIM Comprehensive Application Training	72	ig Data Applications in Construction Information		36	
				Construction Laws and Project Auditing		45	
		Comprehensive Vocational Skill Training for Professional Directions	108				
		Professional Internship Subtotal	342	Professional Extension Courses Subtotal		189	
On-the-Job Internship			600	On-the-Job Internship		600	

Curriculum System Mathematical Model

Based on the comparative scheme of curriculum systems in vocational and higher vocational education outlined earlier, we established a mathematical model to conduct an in-depth analysis of the course hours [11-14].

$$Z = Z1 + Z2 + \ldots Zi \tag{1}$$

$$G = G1 + G2 + \ldots Gi \tag{2}$$

In Formula (1), Z represents the total course hours of all courses at the vocational education stage, and Z1, Z2 ...Zi respectively represent the course hours of individual courses at the vocational education stage, such as Architectural Drawing and Interpretation, Building Structures, Building Materials, etc. [15,16].

In Formula (2), G represents the total course hours of all courses at the higher vocational education stage, and G1, G2, ...Gi respectively represent the course hours of individual courses at the higher vocational education stage, such as Engineering Drawing, Building Mechanics, Building Function and Structural Analysis, etc. [17,18].

Course Hour Comparative Analysis

Based on the mathematical model, the course hours for individual and cumulative courses at vocational and higher vocational stages were calculated. The results are shown in Figure 1 Comparative Diagram of total hoursin Vocational and Higher Vocational Education. From the comparison, it can be observed that the total course hours for vocational education are 2,790 hours, of which 1,728 hours are professional courses. The total course hours for higher vocational education are 2,856 hours, of which 1,810 hours are professional courses. Both systems have a study duration of three years, and the differences in total course hours and professional course hours are minimal.

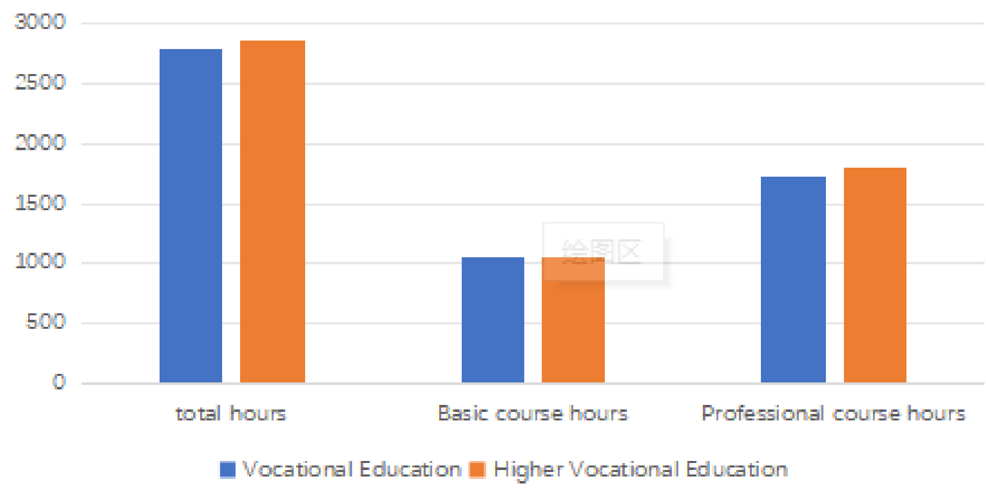

Figure 1. Comparative diagram of total hoursin vocational and higher vocational education

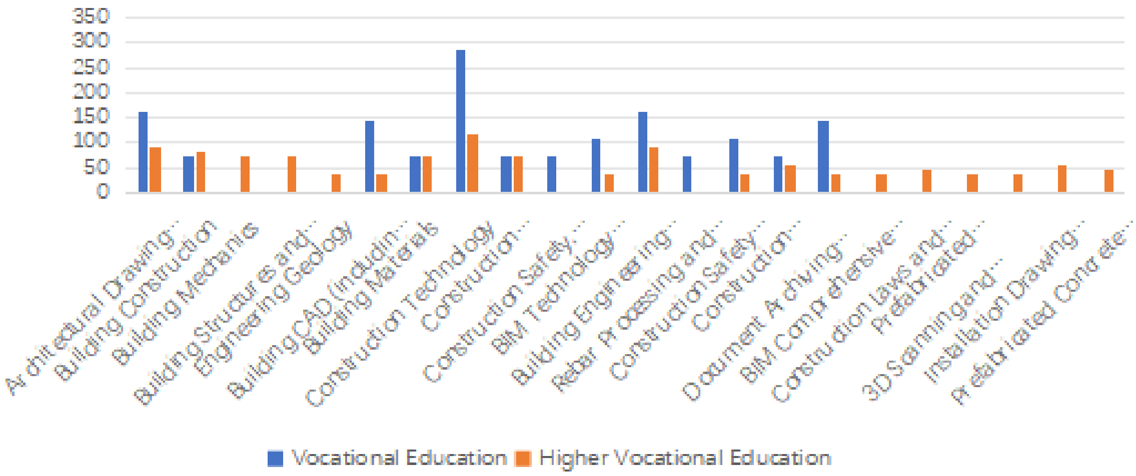

Figure 2. Comparative diagram of core course hours in vocational and higher vocational education

Based on the mathematical model, The results are shown in Figure 2: Comparative Diagram of Core Course Hours in Vocational and Higher Vocational Education**.**From the perspective of course offerings, vocational education provides 19 core professional courses, while higher vocational education provides 28 professional courses [19]. However, focusing on the core courses of this major, both vocational and higher vocational education offer them. Moreover, the course hours allocated for these subjects in vocational education are higher than those in higher vocational education. For the most essential courses in this major—such as Architectural Drawing and Interpretation, Building Structures, Architectural CAD, BIM Technology, Building Materials, Construction Technology, Construction Organization and Management, Engineering Surveying, Construction Safety Management, Construction Measurement and Pricing, and Document Organization—the course hours for several subjects, including Architectural Drawing and Interpretation, Architectural CAD, BIM Technology, Construction Technology, Rebar Processing, Engineering Surveying, Construction Safety Management, and Document Organization, are always higher in vocational education than in higher vocational education. This demonstrates that vocational education places greater emphasis on students mastering basic skills not just to learn them, but to practice and perform them proficiently. Key courses such as Architectural Drawing and Construction, Construction Technology, Building Materials, Architectural CAD, Construction Surveying, and Masonry Construction Technology and Practice are also subjects in the vocational high school entrance examination. Thus, the time allocated for these courses at the vocational stage always exceeds that at the higher vocational stage. Based on the actual skill level of students transitioning from vocational to higher vocational education, they are generally proficient in these areas, indicating that vocational education ensures strong mastery of these specific skills.

In contrast, the higher vocational curriculum includes courses that are not offered in vocational education, such as Building Mechanics, Building Function Analysis, Building Structures, Engineering Geology, Building Laws and Project Auditing, Prefabricated Construction Technology, Installation Drawing Interpretation and Construction Techniques, and Engineering 3D Scanning and Digital Construction Technology. Vocational students do not take mechanics or structural courses because they have not completed middle school physics. Similarly, they do not take courses on building functions due to incomplete middle school solid geometry education. Vocational education offers only Building Structures, as students do not study Engineering Geology because their middle school geography education is incomplete. However, knowledge of geology is essential for civil engineering professionals.

The higher vocational curriculum includes courses such as Prefabricated Construction Technology, Installation Drawing Interpretation and Construction Techniques, Engineering 3D Scanning and Digital Construction Technology, and Building Laws and Project Auditing. These courses cater to the evolving needs of the industry and are designed to meet the requirements of engineers at the Constructor level.

From the perspective of curriculum systems and course hour allocation, higher vocational education places greater emphasis on learning core professional skills. Higher vocational education focuses more on the formulation of solutions and the development of work-related needs in industry-specific job positions, which aligns with its cultivation objectives. This reflects the difference in career goals: vocational education aims to prepare students for roles as construction site personnel, while higher vocational education aims to prepare students for roles as Constructors.

COMPARATIVE ANALYSIS OF CORE COURSE TEACHING CONTENT

In the previous analysis of vocational and higher vocational curriculum systems using a mathematical model, it was evident that some courses have the same names but different allocated hours. This necessitates a further comparison of teaching content to identify the differences in teaching depth and breadth between courses with the same names. Using the talent cultivation programs of the five vocational and five higher vocational colleges mentioned earlier as samples, we have compiled the comparative teaching content scheme shown in Table 4 [20].

Table 4. Comparative analysis of core course

Core Course	Vocational Education Teaching Content	Higher Vocational Education Teaching Content	Remarks
Architectural Drawing and Interpretation	Basic knowledge of architectural drawing Basic knowledge of projection Drawing basic projection diagrams Basic knowledge of architectural engineering diagrams Reading and drawing construction drawings Reading reinforced concrete structural construction drawings Reading reinforced concrete flat structural drawings	Basic knowledge of architectural drawing Basic knowledge of projection Drawing basic projection diagrams Basic knowledge of architectural engineering diagrams Reading and drawing construction drawings	Structural and flat structural drawings are covered under building structure courses in higher vocational education.
Building Materials / Building Materials and Testing Techniques	Basic knowledge of building materials Air-setting cementing materials (lime, gypsum) Hydraulic cementing materials Concrete Building mortar Wall bricks Blocks Structural steel Decorative materials Other building materials	Basic knowledge of building materials Air-setting cementing materials (lime, gypsum) Hydraulic cementing materials Concrete Building mortar Wall bricks Blocks Structural steel Decorative materials Other building materials	
Building Engineering Surveying	Basic knowledge of surveying Level instrument surveying techniques Theodolite surveying techniques Total station surveying techniques GPS surveying techniques	Basic knowledge of surveying Level instrument surveying techniques Theodolite surveying techniques Total station surveying techniques GPS surveying techniques	

	Other tools and instrument surveying techniques (tape measure, distance meter, plumb bob, laser level) Large-scale topographic mapping and application Construction surveying	Other tools and instrument surveying techniques (tape measure, distance meter, plumb bob, laser level) Large-scale topographic mapping and application Construction surveying	
Building Structures / Building Function and Construction Analysis	Residential buildings Foundations Basements Walls Floor systems Vertical traffic facilities Doors and windows Roofs	Plan function analysis Facade analysis Section analysis Residential buildings Foundations Basements Walls Floor systems Vertical traffic facilities Doors and windows Roofs	
Architectural CAD (including Tianzheng)	Basic CAD operations Drawing and annotating gridlines for floor plans Drawing walls, columns, doors, and windows for floor plans Drawing stairs and other external components for floor plans Drawing detailed, enlarged, and interior decoration drawings Drawing elevations Drawing sections, printing, and exporting drawings Drawing structural diagrams Expanded architectural software (Tianzheng)	Basic CAD operations Drawing and annotating gridlines for floor plans Drawing walls, columns, doors, and windows for floor plans Drawing stairs and other external components for floor plans Drawing detailed, enlarged, and interior decoration drawings Drawing elevations Drawing sections, printing, and exporting drawings Drawing structural diagrams Expanded architectural software (Tianzheng)	
Construction Technology	Earthworks Pile foundation engineering Masonry engineering Reinforced concrete engineering Waterproof engineering Decoration engineering Structural hoisting engineering	Earthworks Pile foundation engineering Masonry engineering Reinforced concrete engineering Waterproof engineering Decoration engineering Structural hoisting engineering	
Construction Organization and Management	Overview of construction organization and flow construction Network planning techniques Construction organization design for individual projects Construction project management	Overview of construction organization and flow construction Network planning techniques Construction organization design for individual projects Construction project management (progress, quality, safety)	
BIM Technology / BIM Modeling	Basic knowledge of BIM BIM modeling preparation Component creation, property definition, and parameter setup in BIM Architectural BIM modeling Structural BIM modeling Equipment installation BIM modeling BIM output	Basic knowledge of BIM BIM modeling preparation Component creation, property definition, and parameter setup in BIM Architectural BIM modeling Structural BIM modeling Equipment installation BIM modeling BIM output	
Construction Measurement and Pricing	Basic knowledge of construction cost estimation Composition and application of budget quotas Compilation of construction drawing budgets Integrated methods and construction area calculations Earthworks Pile foundations Masonry engineering Concrete engineering Door and window engineering Roofing, waterproofing, anticorrosion, insulation Decoration project calculations	Understanding related knowledge of construction cost estimation Basic knowledge of construction cost estimation Understanding construction quotas Budget quotas Pricing quotas Cost quotas Calculation methods for construction quantities Rules for calculating construction areas Calculations and examples for subdivided projects: - Earthworks - Ground treatment, slope protection - Pile foundation engineering	

	Other projects (formwork, scaffolding, vertical transportation, additional costs for height increases) Case studies	- Masonry engineering - Concrete engineering - Metal structural engineering - Wooden structural engineering - Door and window engineering - Roofing and waterproofing engineering - Anticorrosion engineering - Floor and ground engineering - General plastering for walls and columns - General plastering for ceilings Preparation of construction budgets Preparation of construction quantity lists Pricing of construction quantity lists	
Document Organization and Management	Basic knowledge of construction document management Construction quality inspection Project management and technical documentation Foundation and substructure documentation Structural documentation Roof documentation Decoration documentation Construction file organization and management	Basic knowledge of construction document management Construction quality inspection Project management and technical documentation Foundation and substructure documentation Structural documentation Roof documentation Decoration documentation Construction file organization and management	

From Table 4, it can be observed that for courses such as Building Engineering Surveying, Construction Technology, Construction Organization and Management, BIM Technology, and Document Organization and Management, the content offered in vocational and higher vocational education is largely consistent. The main reason is that these courses focus on skills that vocational students directly need to apply in the workplace. These courses do not require advanced mathematics or mechanics foundations, making them understandable for vocational students. For instance, in the Construction Technology course, vocational education allocates significantly more hours for the same content compared to higher vocational education, primarily targeting the employment needs of vocational students. In the courses Architectural Drawing and Interpretation and Architectural CAD, vocational education includes more content than higher vocational education. This is because these are purely technical skills that do not require a strong foundational background. Particularly in CAD drafting, once learned, students can directly work as drafters. Conversely, for courses like Building Structures and Construction Measurement and Pricing, higher vocational education offers significantly more content than vocational education. This is because higher vocational education aims to enhance students' capabilities in design skills and construction cost management. These skills align with the professional requirements for Constructors, whose competency structure includes design and cost control capabilities.

CONCLUSION

Through an in-depth analysis of the mathematical models of the civil engineering curriculum systems in vocational and higher vocational education, it is evident that vocational education demonstrates a high level of detail in imparting technical skills and knowledge related to construction processes. Particularly in the critical area of construction technology, vocational education not only offers extensive courses but also allocates substantial course hours. The level of detail even surpasses that of higher vocational education, ensuring that vocational graduates are well-prepared to take on various technical tasks and possess the professional skills to implement technical disclosures effectively. However, it is worth noting that vocational education has certain limitations in cultivating comprehensive professional competencies in students.

Specifically, vocational education often focuses on the rapid acquisition of practical skills while relatively neglecting foundational theoretical subjects such as mechanics and advanced mathematics, as well as the development of in-depth analytical skills for assessing building functionality. For professionals in the construction industry, these theoretical foundations and analytical skills are critical for solving complex problems and formulating solutions for large-scale projects. From the perspective of long-term career development, vocational graduates may face challenges such as insufficient analytical depth and limited capability in solution formulation when dealing with more complex and variable engineering projects. This suggests the need to not only strengthen practical skills education in vocational programs but also appropriately introduce and enhance foundational theoretical education. Doing so would promote the comprehensive development of students' abilities and their potential for sustainable growth.

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