Educational Innovation Research, 2026, Volume 4, Issue 6
https://bbwpublisher.com/journal/EIR
Online ISSN: 3029-1852
Print ISSN: 3029-1844

Precise Industrial Alignment and Vocational Undergraduate Specialty Cluster Development: A Four-Co Mechanism Mapping Framework and Case Study

Xiaochun Zhao, Shasha Peng, Yayue Fu, Meijiu Zhao

Hainan Vocational University of Science and Technology, Haikou 571126, Hainan, China

Abstract: The upgrading of industrial structures and the iterative renewal of job-related technologies require vocational undergraduate education to transform its specialty development paradigm from merely "establishing specialties" to "connecting with industry." To address the disconnect in demand transmission between industry and education, this study develops a four-chain mapping analytical framework comprising the industrial chain, job chain, specialty cluster, and course cluster, grounded in industry-education integration and outcome-based education. It also designs a five-stage iterative mechanism: demand identification, job deconstruction, specialty reorganization, course synergy, and evaluation feedback. The study argues that the job chain is the intermediary structure through which industrial demands enter the educational supply system; the specialty cluster is the organizational unit that carries capacity synergy; and the course cluster is the direct field in which demands are transformed into competencies. Using the Green Intelligent Construction Specialty Cluster at Hainan Vocational University of Science and Technology as a case, this study develops a job competency map, restructures the specialty cluster, reconstructs the curriculum system, and establishes a "co-construction–co-management–co-evaluation–sharing" mechanism for school-enterprise collaborative governance. This creates a dynamic feedback loop in which industrial demands run through the entire cycle of specialty development. The practice offers a replicable theoretical framework and operational paradigm for vocational undergraduate specialty clusters to overcome the "collection of specialties" dilemma and achieve precise alignment with regional industrial structures.

Keywords: Vocational undergraduate education; Specialty cluster construction; Industrial chain; Job chain; Course cluster; Industry-education integration; Intelligent construction

Online publication: June 26, 2026

1. Introduction

There is an inherent supply-demand relationship between vocational education and industrial development. In the current stage of high-quality development, technology iteration cycles have shortened considerably, and the traditional model of specialty development—anchored in specialty catalogs and existing institutional resources—is facing an increasingly severe crisis of adaptability [1]. Supply-side reform in vocational education is no longer merely an internal planning question of "what specialties to offer." Rather, it must address how signals of industrial change are accurately captured, how they are translated into educational language, and how training programs can be iteratively adjusted in response to industrial dynamics. When industry changes, specialties cannot lag; more importantly, industrial signals cannot be left to guesswork—they must be translated into the language of jobs and curricula.

As a key tier of type-based education, vocational undergraduate education is not a simple extension of the higher vocational education system. Instead, while retaining the "vocational" gene of vocational education, it enhances the compoundness and complexity of technical skills, aiming to produce high-end skilled talents capable of undertaking complex technical tasks on the industrial frontline [2]. Policy documents explicitly require vocational undergraduate education to highlight its type positioning, deepen industry-education integration, form a specialty system closely aligned with industrial and innovation chains, and advance the construction of core professional courses and practical evaluation standards in accordance with differentiated requirements for talent types, levels, and structures arising from the division of labor in the industrial chain. However, a notable gap remains between policy vision and grassroots practice: between the dynamic evolution of the industrial chain and the static adjustment of specialty clusters lies a "structural fault in demand transmission" [3].

Existing studies have largely remained at the normative level. For example, some studies summarize the formation models of vocational undergraduate specialty clusters as industry-driven, resource-sharing, and policy-driven, emphasizing that they should serve regional industries and align with job groups [4]. However, these studies lack a mesolevel structural dissection of the mechanism through which industrial demands "enter" specialty settings and further "penetrate" course content and teaching implementation. In short, the academic community has largely answered "where to align" but has not fully resolved "how to align precisely" and "how to achieve dynamic meshing." Accordingly, this paper focuses on three research questions:

RQ1: How are change signals in the industrial chain transformed into operable demand instructions for specialty cluster development?

RQ2: What structural mapping exists among the industrial chain, job chain, specialty cluster, and course cluster?

RQ3: How can institutional design enable specialty clusters to develop dynamic adaptive capacity in response to industrial change?

2. Literature review and theoretical gap

2.1. Vocational undergraduate specialty cluster research: From internal synergy to external adaptation

The understanding of specialty clusters has undergone three progressive stages: the resource-sharing paradigm, which focuses on the optimal allocation of internal teaching resources; the compound cultivation paradigm, which emphasizes cross-specialty synergy; and the industry-driven paradigm, which advocates that specialty clusters should be laid out as a whole in response to regional industrial clusters and job groups [5–6]. In recent years, the industry-driven paradigm has gradually become dominant. However, an epistemological misconception persists: the "industrial chain–specialty cluster" relationship is reduced to a mirror-like direct correspondence, neglecting the complex translation from industrial signals to educational supply [7–8]. This has led, in practice, to the mechanical "patching together" of specialties according to industry names.

2.2. Industrial chain and educational supply: From "loose alignment" to "precise transmission"

The industrial chain is essentially a structured system interwoven with technological activities, enterprise organizations, occupational posts, and work tasks. Industrial digital upgrading cannot directly lead to the simple conclusion that "a digital specialty should be added." From industrial change to educational response, a long transmission chain must be traversed: "technological innovation → industrial task restructuring → job function reconstruction → competency specification reshaping → specialty connotation adjustment → course content updating" [9]. Notably, recent policy guidance from the Ministry of Education implicitly contains this transmission logic. It explicitly requires benchmarking against typical production tasks of leading enterprises, conducting occupational analysis, deconstructing skill points and knowledge points, and then drawing curriculum competency maps. This indicates that job analysis has been formally established as a statutory intermediary link through which industrial demands enter the curriculum system.

2.3. Research gaps

A comprehensive review of existing scholarship reveals three theoretical gaps. First, the missing intermediary layer: between the industrial chain and specialty clusters, there is a lack of a structural intermediary capable of performing a "translation" function [10]. This paper introduces the "job chain" as this intermediary. Second, the blurred transformation point: specialty clusters and course clusters are often discussed separately and are not incorporated into the same transmission chain [11]. This paper clarifies that they are respectively the "organizational carrier" and the "transformation carrier." Third, the broken feedback chain: school-enterprise cooperation mostly focuses on resource input and lacks deep integration at the governance decision-making level [12]. The "Four-Co mechanism" mechanism constructed in this paper aims to address this predicament.

3. Analytical framework: "Four-Co mechanism" and "five-stage iteration"

3.1. Structural definition and functional positioning of the four chains

(1) Industrial chain: source of demand. It delineates the macro boundary and technological direction of talent demand for specialty clusters, providing a "demand portrait" rather than a "construction blueprint" [13].

(2) Job chain: transmitter. This is the core innovation of the framework. The job chain is a structured sequence of job types, levels, and task relationships derived from each link of the industrial chain. It upwardly undertakes changes in industrial technological activities and downwardly deconstructs them into specific work tasks and competency units. It is the hub where industrial logic and educational logic intersect [14].

(3) Specialty cluster: organizational unit. A specialty cluster is not a passive mirror of the industrial chain but a systematic reorganization of related specialties based on the competency commonalities and knowledge connections revealed by the job chain. It aims to form a scaled synergistic supply effect that a single specialty cannot achieve [15].

(4) Course cluster: transformation carrier. The course cluster is the "last mile" of demand implementation. It deconstructs job tasks into knowledge modules, skill training, project practice, and evaluation standards, ultimately producing students' core competencies [16–17].

Core mechanism: The four-Co mechanism is not linearly transmitted. Rather, through the "translation" of the job chain and the "materialization" of the course cluster, industrial demands are gradually settled. Talent cultivation outcomes, through evaluation feedback, in turn affect the talent demand standards of the industrial chain, forming a spiraling ecological closed loop (**Figure 1**).

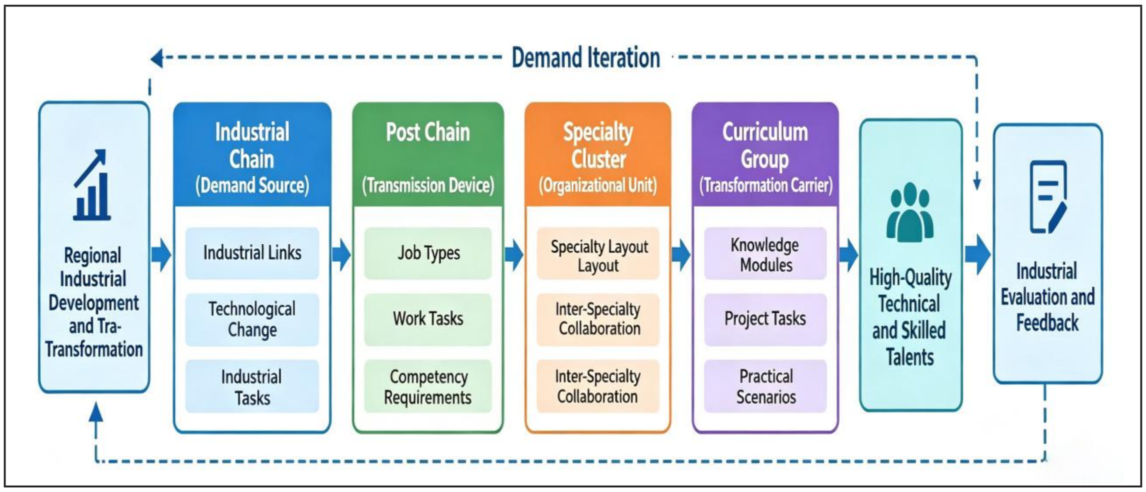

Figure 1. Four-Co mechanism mapping and transmission mechanism of the "industrial chain–job chain–specialty cluster–course cluster." This figure reveals that the four-Co mechanism is not simply linearly corresponding. Through the structural deconstruction of the job chain and the systematic reconstruction of the course cluster, industrial demands are precisely transmitted into talent cultivation competencies, and a dynamic feedback loop is formed through industrial evaluation.

3.2. Operational mechanism of "five-stage iteration"

Based on four-Co mechanism mapping, this paper proposes a five-stage iterative mechanism: "demand identification–job deconstruction–specialty reorganization–course synergy–evaluation feedback" (**Figure 2**). Each stage contains specific operational content. The stages are interlocking and spiraling upward, forming a closed-loop iterative system from industrial demand input to talent cultivation output and then to industrial evaluation feedback.

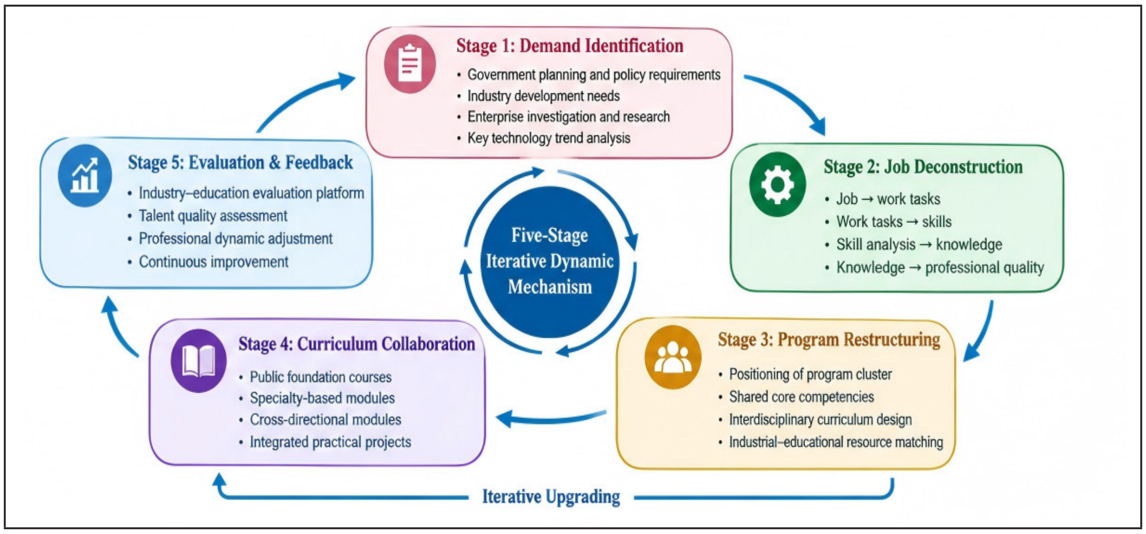

Figure 2. Five-stage iterative operating mechanism for vocational undergraduate specialty cluster construction

4. Research design and methods

4.1. Case selection

This study adopts a single-case study design. The Green Intelligent Construction Specialty Cluster at Hainan Vocational University of Science and Technology was selected for three reasons. First, it is located in the Hainan Free Trade Port, where the construction industry is undergoing digital intelligent transformation. Second, the specialty cluster has been formally recognized as an industry-education integration characteristic specialty cluster, providing rich documentary and practical evidence. Third, the university has established long-term cooperation with enterprises in the intelligent construction field, which makes it possible to observe the transmission process from industrial demand to curriculum reform.

4.2. Data collection

Data were collected from three sources. The first source was semi-structured interviews with enterprise managers, engineers, university administrators, specialty leaders, and graduates. The interview protocol focused on industrial change, job task changes, competency requirements, curriculum updating, and school-enterprise governance. The second source was documentary analysis, including talent cultivation plans, course standards, cooperation agreements, meeting minutes, and project reports. The third source was internal teaching and employment statistics from the university. Quantitative indicators were used only to corroborate the qualitative evidence chain, not to claim strict causal inference.

4.3. Data analysis

The data analysis followed a three-step process. First, the research team coded industrial change signals and job tasks. Second, codes were grouped into competency units and mapped to specialty directions and course modules. Third, the mapping results were compared with the before-and-after reform structure to identify the mechanism of demand transmission. The analysis was conducted iteratively between the theoretical framework and the case evidence.

4.4. Trustworthiness

To enhance trustworthiness, the study used triangulation of interviews, documents, and internal statistics. Preliminary findings were shared with enterprise partners and university administrators for member checking. Where disagreements occurred, the research team returned to the original documents and interview records. The limitations of a single case are acknowledged in the conclusion.

5. Case study: Reform practice of the green intelligent construction specialty cluster

5.1. Industrial transformation: The digital intelligent transformation of the construction industry

The construction industry is undergoing a systematic leap from “construction” to “intelligent manufacturing.” The penetration of new technologies such as BIM technology, prefabricated construction, and digital twin operation and maintenance has not only changed the operation mode of individual jobs but also reshaped the value distribution and technological logic of the entire industrial chain from survey, design, construction, to operation and maintenance [18]. This transformation imposes compound requirements on talents: “proficient in technology, digitally literate, and capable of management."

5.2. Deconstruction of the job chain: From isolated jobs to job clusters

Through in-depth research on key enterprises in Hainan, the research team drew a job competency map for the intelligent construction field (**Table 1**). The map demonstrates significant "commonality of digital technology foundations" and "correlation of engineering practice scenarios" among different jobs, which constitutes the underlying legitimacy of specialty cluster formation.

Table 1. Mapping relationship among the industrial chain, job chain, and course cluster in intelligent construction

Industrial link	Typical job direction	Core work tasks	Key competency requirements	Corresponding core courses/ modules (course cluster carrier)
Survey and design	BIM modeling engineer	Collaborative modeling and clash detection	Digital modeling, spatial collaboration	BIM modeling technology, architectural CAD
Engineering construction	Intelligent construction engineer	Digital construction and site control	Application of intelligent construction processes, project management	Prefabricated building construction, intelligent construction organization
Engineering management	Project director	Full-process schedule and quality control	Comprehensive coordination, risk anticipation and decision-making	Engineering project management, construction regulations
Engineering cost	Digital cost engineer	Full-process cost estimation and control	Digital measurement, cost optimization and control	Digital cost management, BIM measurement and pricing
Operation and maintenance service	Digital O&M manager	Building information maintenance and updating	Information integration, O&M data analysis and decision-making	Building equipment and digital O&M

Source: Compiled based on enterprise research and job competency analysis reports, 2026.

5.3. Reorganization of the specialty cluster and reconstruction of the course cluster: Comparison before and after reform

Based on the mapping relationship in **Table 1**, the university structurally reorganized traditional civil engineering specialties and systematically reconstructed the curriculum system. The core differences before and after the reform are shown in **Table 2**.

Table 2. Structural comparison of specialty cluster construction paradigms before and after reform.

Dimension	Before reform (traditional paradigm)	After reform (four-Co mechanism mapping paradigm)
Clustering logic	Based on similarity of specialty names or resource convenience	Based on competency sharing and industrial relevance of the job chain
Specialty boundaries	Specialties operated independently with clear barriers	Shared foundational platform among specialties, mutual selection of direction modules
Curriculum system	Discipline-oriented courses of "theory + experiment"	Modular course clusters of "task-driven + project-oriented"
Competency cultivation	Focused on single-job operational skills	Covering job groups, emphasizing complex problem solving and digital literacy
Enterprise role	Internship receiver and employment outlet	Co-governance subject of talent cultivation

5.4. "Four-Co mechanism" of school-enterprise collaborative governance

To ensure the efficient operation of the specialty cluster, the university constructed a closed-loop school-enterprise collaborative governance mechanism running through the entire talent cultivation process (**Figure 3**). The enterprise role has been upgraded from the traditional "resource provider" to a "co-governance subject," forming a deep collaborative relationship of "co-construction–co-management–co-evaluation–sharing."

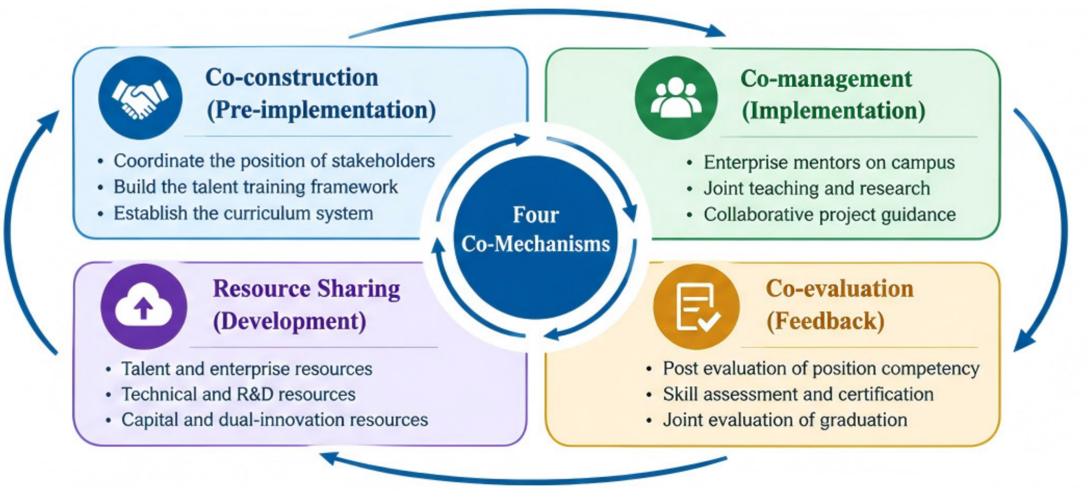

Figure 3. "Co-construction–co-management–co-evaluation–sharing" school-enterprise collaborative governance mechanism. Note: This figure depicts the deep collaboration between schools and enterprises in specialty cluster construction. The four links are connected end to end, forming a closed-loop governance structure from demand input to talent output and then back to resource feedback.

6. Mechanism discussion: Why does four-Co mechanism mapping improve industrial adaptability?

First, introducing the "job chain" as an intermediary achieves a paradigm shift from "macro industrial alignment" to "micro competency translation." Due to the lack of a translation link, the traditional model often leads to formalism in which "specialty names closely follow industry while course content remains unchanged." Four-Co mechanism mapping, through a mandatory job deconstruction procedure, ensures that every course setting can be traced back to specific job tasks and industrial technological activities, fundamentally eliminating the hidden danger of the industry-education disconnect.

Second, replacing "specialty patchwork" with "competency synergy" releases the organizational dividend of specialty clusters. A true specialty cluster is not a resource accumulation of A + B + C but an intensive utilization of teaching resources and cross-incubation of compound competencies through shared foundational job competency modules. This structure expands students' cognition of the occupational world from "pointlike jobs" to a "chainlike ecology," greatly enhancing occupational mobility and sustainable development capacity.

Third, embedding "dynamic feedback" into the governance structure gives specialty clusters the vitality of continuous evolution. Through the spiral ascent of five-stage iteration (**Figure 2**), specialty cluster construction is no longer a rigid plan "finalized once and unchanged for years" but an adaptive and selfcorrecting open system that can keenly follow the pulse of industrial technology and adjust institutional strategies in real time.

The effectiveness of the above mechanism has initially emerged. According to internal statistics, the specialty cluster has signed cooperation agreements with 39 enterprises, the BIM certificate pass rate is 92.8%, students have participated in provincial-level and above skill competitions for a total of 551 person-times in the past three years, and the employment rate in corresponding fields has remained stable above 80% (**Table 3**). Although the above data cannot prove the causal strength between the mechanism and outcomes through strict econometric methods, as part of the evidence chain of case research, they corroborate the endogenous relevance and practical feasibility of the mechanism in a specific context.

Table 3. Key performance indicators of specialty cluster construction

Indicator dimension	Core indicator	Development effect	Evidence source	Statistical scope description
Depth of industry-education integration	Number of cooperating enterprises	39	School-enterprise cooperation agreement ledger	Enterprises with formal cooperation agreements and substantive cooperation projects in the current year
Skill certification level	BIM certificate pass rate	92.80%	Teaching Evaluation Center statistics	Pass rate of students taking the “1+X” BIM vocational skill level certificate examination in that session
Breadth of talent cultivation	Competition participation person-times	551 person-times	Academic Affairs Office competition statistics	Total person-times of students participating in provincial-level and above skill competitions in the past three years
Employment quality effectiveness	Employment rate in corresponding fields	Above 80%	Enrollment and Employment Office employment quality report	Proportion of specialty cluster graduates initially employed in civil construction, cost, BIM, and related positions

7. Theoretical contributions and practical implications

7.1. Theoretical contributions

This paper expands existing cognitive boundaries in three respects. First, it constructs a “four-Co mechanisim mapping” framework (**Figure 1**), breaking the epistemological limitation of treating the “industrial chain–specialty cluster” relationship as a simple correspondence and clarifying the “job chain” as an irreplaceable intermediary variable and the “course cluster” as the key carrier of final transformation. Second, it reveals the “transmission mechanism” of dynamic adaptation of specialty clusters, deconstructing the grand narrative of “industry-education integration” into an operable and replicable technical path of “demand identification–deconstruction–reorganization–synergy–feedback” (**Figure 2**). Third, it promotes the theoretical cognitive upgrade of school-enterprise relations from “resource dependence” to “integrated governance” (**Figure 3**), providing an analytical framework based on governance structure to explain the chronic problem of “integration without depth” in industry-education integration.

7.2. Practical implications

1. Establish a normalized industrial demand scanning radar rather than relying on intermittent subjective judgment.
2. Make "job chain analysis" a statutory prerequisite for specialty cluster construction: first draw the competency map, then determine the specialty combination.
3. Use the "course cluster" to lead curriculum reform, break departmental barriers, form cross-specialty teaching teams, and develop project-based teaching resources.
4. Clarify the list of rights and responsibilities of enterprises in specialty cluster governance in a "contractual" manner, promoting school-enterprise cooperation from "emotional maintenance" to "institutional guarantee."

8. Conclusion

Based on the reform practice of the Green Intelligent Construction Specialty Cluster at Hainan Vocational University of Science and Technology, this paper draws the following conclusions. First, there is no direct correspondence between the industrial chain and specialty clusters; the job chain is the reliable intermediary for demand transmission between them. Second, the core competitiveness of a specialty cluster lies not in the number of specialties but in the "competency synergy ecology" established around the job chain. Third, the course cluster is the key pass for demand transformation; the success of industrial alignment ultimately depends on the mapping precision between course content and job tasks (**Table 1**). Fourth, only by establishing a closed-loop evaluation feedback mechanism (**Figure 2**) can a specialty cluster evolve from a "static system" into a "dynamic life form" resonating with industry.

This study has limitations. First, the qualitative and contextual nature of a single case study means that the external validity of the conclusions needs to be consolidated through multicase comparison. Second, due to limited data accessibility, this paper does not conduct statistical testing of the quantitative mediating effects among the links of four-Co mechanism mapping. Future research can build a quantitative evaluation indicator system of "industrial adaptability–job matching–course responsiveness" and use methods such as structural equation modeling to empirically verify this framework, thereby further enhancing its theoretical explanatory power and universality.

Funding

This work was supported by: (1) the Education Department of Hainan Province, project number Hnjg2026176, "Research and Practice on the 'Post Course Competition Certificate Innovation Research' Talent Cultivation Model for Vocational Undergraduate Specialty Clusters under the Double High Background: A Case Study of the Green Intelligent Construction Specialty Cluster"; (2) the Education and Teaching Reform Research Project of Hainan Vocational University of Science and Technology, "Research on the Construction and Practice of the Green Intelligent Construction Specialty Cluster at Hainan Free Trade Port under the Background of the New Double High Initiative" (HKJG202518); and (3) Research Project on AI-enabled Innovation in Matching Industry-Education Supply and Demand for Majors (Groups) in Vocational Colleges: Research and Practice on AI-driven Dynamic Adjustment of Demand-oriented Vocational Undergraduate Talent Training Programs in Hainan Free Trade Port (KT2605050).

Disclosure statement

The authors declare no conflict of interest.

References

[1] Wu S, 2026, Path Construction for the Vertical Articulation Development of Vocational Education from the Perspective of Systems Science. China Adult Education, 2026(4): 46–56.

[2] Huang Z, Wang K, Zheng L, 2026, A Rational Examination of Cluster Cultivation of High-Skilled Talents from the Perspective of Industrial Cluster Theory. Education and Vocation, 2026(10): 5–14. https://doi.org/10.13615/j.cnki.1004-3985.2026.10.002.

[3] Zhang F, Sun J, 2026, Internal Logic, Realistic Constraints, and Path Exploration of Higher Vocational Education Resources Sinking to County Level: Based on field theory. Chinese Vocational and Technical Education, 2026(5): 5–14.

[4] Song Y, Xu Z, 2024, Harmonious Coexistence: Research on the Formation Models of Specialty Clusters in Vocational Undergraduate Colleges—A Multi-case Study Based on National Vocational Undergraduate Colleges. Chinese Vocational and Technical Education, 2024(16): 86–95.

[5] Kuang Y, Sun Q, 2026, Applied Undergraduate and Vocational Undergraduate: Can Different Paths Lead to the Same Destination? Chinese Vocational and Technical Education, 2026(10): 6–17.

[6] Han T, 2026, The “New Three Transformations” of the Modern Industrial System and Vocational Education Adaptability: Requirements, Characteristics, and Paths. Vocational and Technical Education, 47(10): 14–20.

[7] Zhang K, Li Y, Ma J, 2026, Research on the Construction of Collaborative Mechanisms for the Integrated Development of Education, Science and Technology, and Talent. Human Resources Development of China, 43(1): 126–139. https://doi.org/10.16471/j.cnki.11-2822/c.2026.1.008

[8] Cheng J, Yang X, 2023, Development History, Model Selection, and Repositioning of Industrial Colleges in Higher Vocational Colleges under Industrial Logic. Chinese Vocational and Technical Education, 2023(16): 50–55.

[9] Ji B, Li S, 2026, New Quality Curriculum: The Ideal Vision of Curriculum Development in Higher Vocational Colleges in the Digital-Intelligent Era. Jiangsu Higher Vocational Education, 26(2): 1–12. https://doi.org/10.15903/j.cnki.jniit.2026.02.001

[10] Yang P, Liu Y, 2026, Social Coordination of Skill Formation: A Typological Study of Intermediary Organizations in China’s Industry-education Integration. Chinese Vocational and Technical Education,2026 (9): 21–36 + 57.

[11] Ju C, 2026, Analysis of the Adaptive Development of Specialty Clusters in the Second Phase of the “Double High Plan.” Vocational and Technical Education, 47(15): 32–40.

[12] Que M, Guo J, 2026, From a Major Education Country to an Education Power: Challenges and Strategic Choices for China’s high-quality Education Development during the “15th Five-Year Plan” Period. Journal of Hebei Normal University (Educational Science), 28(1): 11–21. https://doi.org/10.13763/j.cnki.jhebnu.ese.2026.01.002

[13] Han T, He Z, 2026, Cluster Cultivation of High-Skilled Talents: Development Drivers, Core Features, and Action Strategies. Journal of National Academy of Education Administration, 2026(5): 67–75 + 85.

[14] Cui S, Yao C, 2023, Internal Logic, Target Positioning, and Implementation Paths of Talent Cultivation in Undergraduate-Level Vocational Education. Modern Education Management, 2023(4): 97–108. https://doi.org/10.16697/j.1674-5485.2023.04.010

[15] Su M, Huang J, Zhai W, et al., 2024, Accelerating the Implementation of New Quality Productive Forces to Promote the Establishment and Improvement of a Modern Industrial System. Journal of Industrial Technological

Economics, 43(12): 21–41.

[16] Hu S, Yao Y, 2025, New quality productive forces empowering vocational education: Current status of talent cultivation, value orientation, and practical paths. Vocational Technology, 24(8): 30-36. https://doi.org/10.19552/j.cnki.issn1672-0601.2025.08.005

[17] Xi M, Cai F, Ma C, 2026, Typical Models, Realistic Challenges, and Optimization Paths of Intelligent Manufacturing Talent Cultivation in Higher Vocational Colleges from the Perspective of New Quality Productive Forces. Education and Vocation, 2026(8): 68–76. https://doi.org/10.13615/j.cnki.1004-3985.2026.08.007

[18] Editorial Department of China Journal of Highway and Transport, 2024, Review of Academic Research on Bridge Engineering in China—2024. China Journal of Highway and Transport, 37(12): 1–160. https://doi.org/10.19721/j.cnki.1001-7372.2024.12.001