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Research on the Evolution of Industrial Clusters in Free Trade Ports and the Dynamic Adaptability of Professional Layouts in Hainan Universities: A Perspective Based on Supply-Demand Matching through Industry-Education Integration

Yude Jiang, Wusen Qiu*
Hainan Vocational University of Science and Technology, Haikou 571126, Hainan, China

Author to whom correspondence should be addressed.

Abstract: The development of the Hainan Free Trade Port has accelerated the evolution of industrial clusters toward a modern "45432" industrial system, creating a growing demand for high-caliber, application-oriented, and internationally competent talents characterized by scale, complexity, and cutting-edge expertise. As the core vehicle for talent supply, the strategic alignment of university programs with industrial cluster development directly influences the cultivation of the Free Trade Ports advanced productive forces and its high-quality growth. This study examines the evolutionary stages and features of Hainans industrial clusters through the lens of industry-education integration and supply-demand matching. It analyzes the current state and limitations of university program structures, establishes a dynamic adaptation framework of "demand-driven–supply-responsive–collaborative coupling" and proposes a precision-adjustment mechanism for programs aligned with industrial and innovation chains alongside a collaborative governance pathway for industry-education integration. These findings provide theoretical foundations and practical guidance for harmonizing the education, talent, industrial, and innovation chains within the Free Trade Port.

Keywords: Free trade port industrial clusters; University program distribution; Dynamic adaptability; Industry-education integration; Supply-demand matching

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1. Introduction

Since the establishment of the Hainan Free Trade Port, industrial clusters centered around the "45432" modern industrial system have accelerated their evolution, forming a new industrial landscape comprising "four leading industries + three future industries + four advantageous industries + three consumption-driven sectors + two strategic platforms". By 2025, Hainan had cultivated three industrial clusters each valued at hundreds of billions, petrochemical new materials, modern finance, and modern commerce, as well as two clusters each valued at tens of billions: the food industry and modern seed

industry. The operating revenue of 13 key industrial parks exceeded 2.5 trillion yuan. The evolution of these industrial clusters is characterized by three key features: chain supplementation, extension, and upgrading; cultivation of new-quality productive forces; and open, integrated development. The demand for talent has shifted from traditional, single-skilled roles to a composite profile encompassing "specialization + skills + global perspective + innovation capability", particularly for professionals in future industries such as seed production, deep-sea exploration, and aerospace, as well as in emerging sectors like the digital economy, biopharmaceuticals, and low-altitude economy [1].

Hainan currently has 28 regular higher education institutions, forming a higher education system that covers undergraduate, vocational, and postgraduate programs. However, the alignment between academic program offerings and the evolving industrial clusters remains inadequate, resulting in issues such as outdated program offerings, structural imbalances, and a disconnect between supply and demand. The pace of university program adjustments fails to keep up with the rapid evolution of industrial clusters, exacerbating the structural contradiction in the free trade port where there is a severe shortage of urgently needed talent while university graduates face employment challenges. Deepening industry-education integration and ensuring dynamic alignment between university program offerings and industrial cluster development have become crucial pathways to overcoming the talent bottleneck in the free trade port and facilitating industrial upgrading [2].

2. Core concepts and theoretical foundations

2.1. Definition of core concepts

(1) The evolution of industrial clusters in the free trade port

Leveraging its policy and resource advantages, Hainan Free Trade Port has witnessed a dynamic transformation of its industrial clusters, from single-industry concentrations to models characterized by "collaborative industrial chains, integrated innovation ecosystems, and open development". This process encompasses three phases: optimization of dominant industries, cultivation of future industries, and expansion of emerging sectors, demonstrating features of "chain supplementation and extension, innovation-driven growth, and open integration".

(2) Dynamic adaptability of university program structures

Universities in Hainan dynamically adjust their program offerings, structures, and scales in response to the developmental stages of industrial clusters and evolving talent demands, ensuring precise alignment and synergistic development between program offerings and industrial/innovation chains across three dimensions: structural alignment, scale alignment, and quality alignment [3].

(3) Integration of industry and education for supply-demand alignment

Guided by industrial demands and supported by university offerings, this approach facilitates precise alignment between talent supply and industrial/innovation needs through collaborative efforts among governments, universities, enterprises, and research institutions, thereby promoting deep integration of the education chain with industrial and innovation chains.

2.2. Theoretical basis

(1) Industrial cluster evolution theory

Industrial clusters undergo four stages, formation, growth, maturity, and upgrading, driven by agglomeration effects, innovation effects, and synergistic effects to facilitate industrial upgrading. Their evolving talent demands provide a driving force for adjusting university program offerings.

(2) The theory of dynamic adjustment in higher education

University program offerings must align with regional economic and social development needs, establishing a dynamic mechanism of "demand monitoring–dynamic adjustment–quality evaluation" to achieve precise alignment between academic programs and industrial/social demands.

(3) The theory of collaborative governance for industry-education integration

Multiple stakeholders achieve cross-domain and cross-sector collaboration through institutional norms, resource sharing, and interest coordination, addressing the fragmentation between disciplinary layout and industrial evolution while facilitating efficient supply-demand matching [4].

(4) The new quality productivity theory

With technological innovation as the driving force and data as the key element, it promotes the digital, intelligent, and green transformation of industries, imposing requirements for universities program structures to be "innovative, cutting-edge, and interdisciplinary", thereby enabling dynamic adaptive practices.

3. Evolution stages and characteristics of industrial clusters in the Hainan free trade port

3.1. Division of evolutionary stages

(1) Agglomeration formation stage (2018–2020)

The free trade port construction commenced, leveraging policy incentives to drive initial industrial clustering. Focus was placed on developing traditional advantageous industries such as tourism and tropical specialty high-efficiency agriculture, forming preliminary industrial frameworks centered around industrial parks with small-scale, low-tier clusters.

(2) Growth and upgrade stage (2021–2024)

Centered on the "4 + 3 + 3" industrial system, efforts prioritized strengthening and extending core industrial chains while nurturing emerging sectors. Industrial clusters like Yangpu Petrochemical New Materials and Yazhou Bay Seed Industry accelerated their expansion, significantly enhancing industrial agglomeration effects and driving substantial growth in talent demand.

(3) High-quality evolution stage (2025–present)

Fully aligned with the "45432" modern industrial system, the region cultivated new quality productive forces, expanded three future-oriented industries, seed industry, deep-sea exploration, and aerospace, then promoted cluster upgrades toward high-end, intelligent, and integrated development, with talent demands exhibiting increasingly interdisciplinary and cutting-edge characteristics [5].

3.2. Core features

(1) Systematization of the industrial ecosystem

Establish a comprehensive industrial system comprising "four leading industries (tourism, modern service industries, high-tech industries, and tropical specialty efficient agriculture) + three future-oriented industries (seed industry, deep-sea exploration, and aerospace) + four advantageous industries (petrochemical new materials, green and low-carbon industries, digital economy, and marine industries) + three key consumption sectors (island duty-free shopping, healthcare, and education) + two strategic platforms (International Tourism and Consumption Center, Nanfan Silicon Valley)", enabling coordinated development of industrial clusters.

(2) Led by new quality productivity drivers

Focusing on sectors such as offshore wind power, artificial intelligence, biomanufacturing, and the low-altitude economy, efforts are made to advance industrial digital transformation. Industrial clusters like Haikous biopharmaceutical sector and Chengmais deep-sea oil and gas sector have been recognized as national-level distinctive industrial clusters.

(3) Deepened openness and integration

Leveraging the opportunities presented by customs-free operations, industries are aligned with international rules. Initiatives such as Yangpu Port and Shipping and the Lingshui International Education Innovation Pilot Zone have

achieved open integration, attracting high-quality domestic and international industrial resources and fostering emerging industrial clusters in cross-border e-commerce and international logistics.

(4) Support from key parks

Thirteen key parks serve as core platforms for industrial clusters, with projected annual revenue exceeding 2.5 trillion yuan by 2025. This has established a synergistic development model of "park + industry + talent", providing practical support for specialized industrial layouts [6].

4. Current status and adaptability analysis of academic program structures in Hainan universities

4.1. Current status of professional layout

(1) Disciplinary structure

Hainans higher education institutions cover 12 major disciplines: philosophy, economics, law, education, literature, history, science, engineering, agriculture, medicine, management, and arts. Among these, tropical agriculture, tourism management, and marine science are distinctive and advantageous disciplines that align closely with the free trade ports traditional strengths.

(2) Program scale

As of 2025, Hainans universities offer over 200 undergraduate programs and more than 150 vocational programs. Eight new undergraduate programs have been added, including Marine Fisheries Science and Technology, International Journalism and Communication, and Energy Storage Science and Engineering. The number of programs continues to expand, gradually covering the key industries of the free trade port.

(3) Key development priorities

Universities such as Hainan University and Hainan Normal University focus on establishing programs in tropical agriculture and forestry, marine science and technology, and tourism management; vocational colleges concentrate on skill-oriented disciplines urgently needed by the free trade port, including tourism management, e-commerce, and marine engineering; the Lian International Education Innovation Pilot Zone collaborates with overseas universities to develop international programs in global education and cross-border finance.

(4) Industry-education integration practices

A number of modern industrial colleges and industry-education integration training bases have been established, implementing educational models such as "order-based training, apprenticeship systems, and dual mentorship". Hainan University jointly established the Nanfan Industrial College with Yazhou Bay Science and Technology City, while Hainan Vocational College of Economics and Trade cooperated with Yangpu Port to cultivate logistics professionals, demonstrating initial success in industry-education integration [7].

4.2. Current status of dynamic adaptability

From the perspective of supply-demand alignment in industry-education integration, the analysis is conducted across three dimensions: structural alignment, scale alignment, and quality alignment. Structural alignment reveals partial alignment with prominent gaps, the Tropical Agriculture and Forestry program aligns with tropical specialty and high-efficiency agriculture; the Tourism Management program aligns with the tourism industry; the Marine Science program aligns with marine industries, demonstrating strong alignment with the traditional pillar industries of the free trade port. However, alignment shortcomings include shortages in future-industry programs, lagging program development in fields such as seed industry, deep-sea exploration, and aerospace (only a few Hainan universities offer programs like Marine Engineering and Seed Science and Engineering); insufficient coverage of emerging industries, with limited and underdeveloped programs in areas like digital economy, biomedicine, and low-altitude economy; and inadequate interdisciplinary integration, lacking cross-industry and cross-disciplinary programs that hinder the cultivation of versatile professionals.

(1) Scale adaptation

Insufficient total volume and structural imbalance.

(2) Supply volume

The free trade port faces a talent shortage of over 150,000 in key industries, while annual university graduate numbers remain around 50,000, resulting in a severe shortage of talent supply.

(3) Structural imbalance

Excess graduates from traditional majors, with low employment rates for fields like tourism management and Chinese language and literature; insufficient supply in high-demand disciplines such as aerospace technology, deep-sea engineering, cross-border finance, and artificial intelligence, failing to meet industry needs.

(4) Quality adaptation

Quality needs improvement with a supply-demand gap. University talent cultivation emphasizes theory over practice, featuring outdated curricula lacking cutting-edge industry technologies and international standards, leaving graduates with inadequate practical skills, innovation capabilities, and global perspectives.

(5) Supply-demand mismatch

Professional training programs fail to align with industry job requirements, with limited corporate involvement in curriculum development, making it difficult to achieve the goal of "graduation equals employment, immediate job readiness".

4.3. Causes of adaptation bottlenecks

(1) The absence of a dynamic adjustment mechanism for academic programs

No system has been established for monitoring industry demands, providing early warnings for program adjustments, or enabling rapid responses. Program offerings lag behind the evolution of industrial clusters, resulting in lengthy adjustment cycles and slow responsiveness in universities.

(2) Insufficient integration of industry and education

Enterprises show limited enthusiasm in participating in program development, with a tendency to prioritize workforce supply over talent cultivation. Resource sharing between schools and enterprises remains inadequate, practical training bases are underdeveloped, and there is a shortage of dual-qualified teachers, making it difficult to achieve precise alignment between academic programs and industry needs.

(3) Insufficient collaboration among multiple stakeholders

The government lacks effective coordination, failing to establish a coordinated mechanism among education, industry, and talent sectors; universities demonstrate weak institutional initiative and insufficient capacity for proactive industry engagement; industry associations are absent and fail to fulfill their roles in setting talent standards and facilitating supply-demand matching.

(4) Inefficient allocation of resources

Universities possess limited operational resources and underinvest in programs targeting future and emerging industries; the industry-education integration information platform remains inadequate, resulting in information asymmetry regarding talent supply and demand that hinders precise matching.

5. Construction of a framework for the evolution of industrial clusters and dynamic alignment of university program offerings

5.1. Adaptation logic

The core logic underlying the dynamic adaptation between the evolution of free trade port industrial clusters and university program structures is "demand-driven–supply-responsive–collaborative coupling": Changes in talent demand arising from industrial cluster evolution are transmitted to universities through the industry-education integration supply-demand

matching mechanism; universities dynamically adjust their program offerings in response to these demands, optimizing the supply side; collaborative governance by multiple stakeholders ensures efficient operation of the adaptation mechanism, ultimately fostering a virtuous cycle of deep integration among the education chain, industrial chain, and innovation chain [8].

5.2. Adaptation dimensions and indicators

Adaptation dimension	Core indicator	The evolving needs of industrial clusters
Structure adaptation	Professional coverage, professional relevance, and interdisciplinary integration	Cover the "45432" industrial system; align with the needs of future and emerging industries; support the cultivation of interdisciplinary talents
Scale adaptation	The alignment of enrollment capacity, the supply of graduates, and the coverage rate of talent shortages	Meet the large-scale demand for industry talents; address the shortage of scarce talents; and reduce the talent gap.
Quality adaptation	Talent quality alignment rate, practical competency achievement rate, and international perspective achievement rate	Aligned with the skill requirements of industry positions; possesses practical innovation capabilities; meets the openness demands of the free trade port.
Collaborative adaptation	Participation level in industry-academia integration, rate of joint program development, and coverage rate of practical training bases	Enterprises are deeply involved in program development; schools and enterprises jointly establish programs; there are ample practical training scenarios.

5.3. Adaptive path

(1) Demand side

Establish a dynamic monitoring system for industrial talent demand. Establish a monitoring mechanism for talent demand in free trade port industrial clusters, collaborating with industry associations, leading enterprises, and key parks to regularly publish industrial talent demand reports, lists of scarce positions, and skill standards, while dynamically tracking changes in the quantity, structure, and quality requirements of talent driven by cluster evolution.

(2) Supply side

Establish a dynamic adjustment mechanism for university programs. Guided by industrial demands, develop a closed-loop adjustment mechanism encompassing "demand monitoring–program evaluation–adjustment decision-making–quality assessment". This involves adding programs in high-demand fields of future and emerging industries, upgrading traditional programs, and phasing out redundant or low-employment-rate programs, thereby creating a program system closely aligned with industrial chains.

(3) Collaborative dimension

Deepening the integration and collaborative governance of industry-education partnerships. Promote multi-stakeholder collaboration among governments, universities, enterprises, and research institutions to jointly establish industry-education consortia and sector-specific industry-education integration communities. Advance joint program development, collaborative curriculum design, shared faculty training, and centralized practical training resources to achieve precise alignment between supply and demand.

6. A Collaborative governance path for industry-education integration with enhanced dynamic adaptability

6.1. Establish a professional dynamic adjustment mechanism to precisely align with industrial evolution

(1) Establish a demand monitoring and early warning mechanism

Develop a provincial-level industry-education integration information sharing platform to integrate data on industrial talent supply and demand, program development, and employment quality. Create a talent supply-demand early warning model and publish a biannual white paper on industrial talent demand forecasts to provide data support for

program adjustments.

(2) Optimize the program establishment process

Simplify the program approval procedures to enable universities to rapidly establish urgently needed programs for the free trade port, such as deep-sea technology, aerospace engineering, biomanufacturing, and low-altitude economy; Establish a dynamic program evaluation mechanism that issues yellow or red alerts for programs with low relevance, requiring timely adjustments or revocation.

(3) Enhancing the alignment between professional clusters and industrial clusters

Centering on the free trade ports "45432" industrial framework, Hainan University has established professional clusters structured around "key industries–core disciplines–supporting courses". This initiative facilitates the integration of its tropical agriculture and forestry program cluster with the Nanfan Seed Industry, while its tourism program cluster at Hainan Vocational College of Economics and Trade connects with the International Tourism and Consumption Center, achieving precise alignment between academic programs and industrial needs.

6.2. Deepen industry-education integration and collaborative talent cultivation to enhance the quality of talent supply

(1) Co-building modern industrial colleges

Support leading enterprises and universities in jointly establishing modern industrial colleges, such as the Nanfan Industrial College, Deep Sea Industrial College, and Aerospace Industrial College, to collaboratively develop talent cultivation programs, design curriculum systems, implement teaching processes, and promote an integrated education approach combining job requirements, courses, competitions, certifications, and innovation initiatives.

(2) Strengthening the development of dual-qualified faculty teams

Establish a two-way talent mobility mechanism between schools and enterprises, support university teachers in undertaking rotational assignments in enterprises, and recruit highly skilled professionals and key management personnel from enterprises to serve as part-time instructors in universities. By 2025, the proportion of dual-qualified teachers in vocational schools shall be no less than 60%, while the proportion of part-time teachers from enterprises shall be no less than 20%.

Enhance industry-academia integrated training bases by establishing "factories within universities and universities within factories", virtual simulation training centers, and innovation and entrepreneurship incubation bases. This initiative encourages universities to open their laboratories to enterprises and enterprises to share their production environments with universities, ensuring seamless alignment between teaching processes and production workflows, as well as between training content and job-specific skills.

6.3. Improve collaborative governance among multiple stakeholders to ensure effective and sustainable operation

(1) Strengthening government coordination and leadership

Establish a provincial-level industry-education integration leadership group to coordinate educational, industrial, talent, and technological resources; issue regulations on industry-education integration for the free trade port to clarify the rights and responsibilities of multiple stakeholders; increase fiscal investment by setting up special funds for industry-education integration to support projects such as program adjustments and training base development.

(2) Stimulating enterprise vitality

Cultivate industry-education integrated enterprises; introduce certification standards and incentive policies offering tax reductions and financial support to companies involved in program development and talent cultivation; support enterprises in leading the formation of industry-specific industry-education integration communities to actively participate in program planning and talent development.

(3) Leverage the bridging role of industry associations

These associations establish industry talent standards and professional education standards, create platforms for school-enterprise collaboration, conduct talent evaluation and quality supervision, and ensure precise alignment between academic programs and industrial standards.

(4) Promote independent reform in higher education institutions

Universities proactively engage with industrial clusters, optimize their disciplinary and program structures, establish mechanisms for autonomous program adjustments, deepen reforms in talent cultivation models, and enhance institutional vitality and adaptability.

6.4. Strengthen digital empowerment to enhance adaptation efficiency

Establish a digital industry-education integration platform that leverages next-generation information technologies such as big data, artificial intelligence, and virtual simulation. Develop a provincial-level free trade port industry-education integration big data center to integrate industrial operation data, talent demand data, university program data, graduate employment data, and enterprise job data, thereby creating a digital closed-loop system of "demand-supply-matching-feedback". Through intelligent algorithms, the platform analyzes real-time trends in industrial cluster evolution and changes in talent gaps, providing precise data support for dynamic adjustments to university programs and reducing the arbitrariness and lag in program establishment.

Promote the digital transformation of professional development by encouraging universities to develop digital course modules, virtual simulation training projects, and industrial digital twin teaching scenarios in emerging fields such as the digital economy, low-altitude economy, artificial intelligence, and blockchain, thereby facilitating the transition of traditional majors toward a "major + digital technology" model. Support universities in establishing online industry colleges, intelligent learning platforms, and cross-university/cross-major credit recognition systems to enhance the flexibility and adaptability of program offerings, ensuring that talent cultivation aligns with industrial digital transformation.

Establish a smart employment and supply-demand matching system that utilizes digital platforms to create graduate competency profiles and an intelligent job-matching mechanism for enterprises. This system delivers targeted employment information, internship opportunities, and training programs, enhancing the alignment efficiency between talent supply and industrial job requirements. Meanwhile, through an employment quality tracking and feedback mechanism, universities are incentivized to continuously optimize curriculum content, practical components, and training objectives, fostering a virtuous cycle of ongoing improvement in program offerings.

6.5. Highlight the distinctive features of the free trade port and promote the international alignment of its professional layout

In alignment with international high-standard economic and trade rules, and leveraging the institutional advantages of the free trade port, including customs clearance operations, zero tariffs, low tax rates, and a streamlined tax system, this study has introduced in-demand programs such as International Economics and Trade, Cross-border Finance, International Law, International Logistics, Customs Supervision, and Foreign Accounting. These initiatives strengthen the cultivation of competencies in international rules, foreign language application, and cross-cultural communication, ensuring the program structure deeply meets the high-level opening-up requirements of the free trade port.

This study has introduced high-quality overseas educational resources for coordinated development, leveraging platforms such as the Lingshui Lian International Education Innovation Pilot Zone and the Boao Lecheng International Medical Tourism Pilot Zone. This initiative supports joint Sino-foreign cooperative education programs between overseas universities and Hainan institutions, fostering the establishment of international professional clusters. By incorporating international vocational qualification certification systems, global curriculum standards, and overseas industrial resources, further aim to align professional talent cultivation standards with international benchmarks and enhance our capacity to supply globally competitive talent.

To meet the demands of the Belt and Road Initiative and regional cooperation, and leveraging Hainan Free Trade Ports strategic location facing Southeast Asia and connecting the Pacific and Indian Oceans, the program has introduced new specializations such as less commonly taught languages, cross-border e-commerce, international cultural tourism, maritime cooperation, and regional and country studies. These initiatives aim to cultivate versatile talents with global perspectives, regional understanding, and foreign service capabilities, ensuring that the program structure not only supports local industrial upgrading but also underpins the development of the free trade port as an international gateway hub.

7. Research conclusion

This study, grounded in the perspective of supply-demand alignment through industry-education integration, systematically examines the dynamic compatibility between the evolution of industrial clusters in the Hainan Free Trade Port and the academic program offerings at universities. The key findings are as follows: First, Hainans industrial clusters have transitioned from initial aggregation to a new phase of high-quality development, forming a framework centered on the "45432" modern industrial system, consolidating core industries, nurturing future-oriented sectors, expanding emerging industries, and deepening international integration. The talent demands exhibit four distinctive characteristics: multidisciplinary, cutting-edge, practice-oriented, and global-focused, providing clear direction and essential requirements for university program development. Second, while Hainans academic program offerings show some alignment with traditional dominant industries, they lag significantly behind the rapid evolution of industrial clusters: severe shortages in programs for future industries, incomplete coverage of emerging sectors, low interdisciplinary integration, and dual deficiencies in both the quantity and quality of talent. These structural supply-demand imbalances stem fundamentally from the absence of dynamic program adjustment mechanisms, insufficient industry-education integration, and weak collaborative governance among stakeholders. Third, the dynamic alignment between industrial clusters and academic programs constitutes a systemic process driven by demand, responsive supply, and synergistic coupling. An evaluation framework should be established across four dimensions: structural alignment, scale alignment, quality alignment, and collaborative alignment. The integration of industry and education serves as a bridge to achieve effective alignment among the education chain, talent chain, industrial chain, and innovation chain. Fourth, enhancing dynamic adaptability requires a systematic governance approach: establishing a mechanism for monitoring industrial talent demands and dynamically adjusting academic programs; deepening the development of industry-education integration platforms such as modern industrial colleges, training bases, and dual-qualified faculty teams; and improving the collaborative governance framework involving governments, universities, enterprises, and industry associations. Driven by both digitalization and internationalization, this approach ensures continuous optimization of academic program offerings in response to the evolution of industrial clusters.

Overall, only by keeping pace with the industrial cluster upgrading in the Free Trade Port and adhering to the principles of aligning education with industry needs, leveraging education to boost industry development, and fostering symbiosis between industry and education can Hainans higher education institutions effectively address the talent supply-demand mismatch, thereby providing sustained talent support for cultivating new-quality productive forces and achieving high-quality development in the Free Trade Port.

8. Countermeasure recommendations and future prospects

8.1. Countermeasure recommendations

Accelerate the establishment of a professional dynamic adjustment mechanism encompassing "early warning–exit–addition", using the satisfaction level of industrial talent demand, the employment rate aligned with program offerings, and the depth of industry-education integration as core evaluation indicators. For programs with consistently low alignment and poor employment outcomes, implement enrollment reductions, suspension, or cancellation; for urgently needed

programs in key and future industries within the free trade port, establish “green channels” to facilitate a dynamic program structure characterized by continuous entry and exit, and survival of the fittest.

The “One Industry, One Specialized Cluster” alignment initiative is being implemented, focusing on key sectors such as the Nanfan seed industry, deep-sea technology, aerospace industry, cultural and tourism consumption, digital economy, biomedicine, and low-altitude economy. Led by the government with participation from leading enterprises and execution by universities, corresponding specialized clusters are being developed one by one, establishing a precise matching framework where “wherever industries develop, specialized programs follow”.

Expand the coverage of enterprises integrating industry and education with industrial colleges, introduce more attractive fiscal, tax, land, and financial incentive policies, and significantly enhance enterprises enthusiasm for participating in professional development and talent cultivation. Encourage key industrial parks and universities to jointly establish industry-education consortia, promote integrated talent cultivation through the “park + university + enterprise” model, and effectively transform industrial resources into educational resources.

Enhance the industry-aligned capabilities of the teaching faculty by establishing a regular mechanism for university professors to undertake frontline industrial assignments and for corporate technical experts to teach on campus. Support universities and enterprises in jointly forming innovative teaching teams and industry mentor databases, thereby comprehensively improving faculty proficiency in cutting-edge technologies, industrial processes, and international regulations.

8.2. Future outlook

With the full implementation of the Hainan Free Trade Ports customs clearance operations and the accelerated emergence of new quality productive forces, industrial clusters are evolving toward higher-end, more open, and more integrated directions, imposing greater demands on the dynamic adaptability of university program offerings. Future research could focus on: the establishment and innovative training models for international-related programs and rule-aligned disciplines under the customs clearance framework; the transformative impact of technologies such as generative AI and digital twins on program structures and teaching methodologies; the design of long-term mechanisms for shared benefits, cost-sharing, and risk-sharing in industry-education integration within the free trade port; and the differentiated positioning and collaborative division of labor among various types of universities (research-oriented, application-oriented, and vocational colleges) in their program offerings.

By continuously deepening the integration of industry and education, Hainans universities are fostering a professional ecosystem that is highly aligned with the free trade ports industrial system, dynamically adaptive, and collaboratively upgraded, thereby establishing a virtuous cycle where “the prosperity of industry drives educational advancement, and the strength of talent enhances the free trade port”.

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