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Research on Innovative Forms of Industry-Education Integration and Talent Supply-Side Reform in Universities under the Background of Digital Free Trade Port: Taking Hainan Cultural Tourism and Health Care Industry Cluster as an Example

Xueke Peng*
Hainan Vocational University of Science and Technology, Haikou 571126, Hainan, China

****Author to whom correspondence should be addressed.***

Abstract: Against the backdrop of digital transformation and island-wide customs operations in Hainan Free Trade Port, cultural tourism and healthcare industry clusters are accelerating their evolution toward intelligentization, internationalization, and integration, creating urgent demands for digital, interdisciplinary, and global talent. Current university talent supply faces structural challenges including outdated professional frameworks, superficial industry-academia integration, weak digital literacy, and insufficient practical skills. Grounded in the digital free trade port strategy, this study analyzes the digital transformation characteristics and evolving talent needs in cultural tourism and healthcare sectors. It explores four innovative models for industry-academia collaboration: digital-intelligent integration, scenario-based approaches, ecosystem development, and global alignment. The research proposes a five-pronged talent supply-side reform pathway encompassing professional restructuring, curriculum iteration, practice redesign, faculty upgrading, and institutional innovation. Supported by Hainan's case studies, this study provides talent assurance and theoretical references for high-quality development of the free trade port's cultural tourism and healthcare industries.

Keywords: Digital free trade port; Industry-education integration; Innovative models; Talent supply-side reform; Cultural tourism and health care industry cluster

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1. Introduction

As a national flagship platform for high-level opening-up, Hainan Free Trade Port is vigorously advancing the development of a "Digital Free Trade Port". Policies such as the Hainan Free Trade Port Digital Economy Promotion Regulations and the Data Outbound Management List have been implemented, enabling seamless cross-border data flow and enhancing new infrastructure including international submarine cables and computing power centers. With an annual digital economy output exceeding 200 billion yuan, the region provides institutional and technological support for

industrial digital transformation. Leveraging free trade port policies and ecological advantages, Hainan's leading cultural tourism and wellness industries are rapidly forming integrated clusters combining tourism, culture, healthcare, and digital technologies. Emerging sectors like smart tourism, digital cultural heritage preservation, cross-border travel experiences, intelligent wellness services, and medical tourism are experiencing explosive growth [1].

The digital transformation of industries is driving fundamental changes in talent supply. Currently, higher education institutions in Hainan still face challenges in cultivating cultural tourism and wellness professionals, including outdated program structures, obsolete curricula, insufficient industry-academia collaboration, and a lack of digital competencies, resulting in a significant structural mismatch between talent supply and industrial demands. Against this backdrop, exploring innovative models of industry-education integration within the digital free trade port framework, advancing talent supply-side reforms in universities, and achieving deep alignment between educational systems, talent pipelines, and the cultural tourism wellness industry chain as well as innovation ecosystems hold both strategic significance and practical value.

2. Core concepts and theoretical foundations

2.1. Definition of core concepts

2.1.1. Digital free trade port

Centered on secure and orderly data flow, this model leverages digital infrastructure, institutional innovation, and technological applications to drive digital transformation across trade, investment, industries, and governance. It represents an open economic paradigm characterized by cross-border data facilitation, digital industrial clustering, and deep industrial digitization. Cultural-Tourism-Wellness Industry Cluster: Focusing on cultural, tourism, and wellness sectors, this ecosystem integrates digital technologies, ecological resources, and humanistic elements through spatial convergence and collaborative synergy among upstream/downstream enterprises, research institutions, and service platforms. Its core lies in the deep integration of "cultural tourism + wellness" with digital and intelligent upgrades. Industry-Education Integration: This dynamic process involves profound collaboration between education and industries in talent cultivation, technological innovation, and resource sharing. By consolidating educational and industrial resources, it achieves precise alignment between talent supply and industrial demands, serving as a crucial model for organic integration of educational systems, talent pipelines, industrial chains, and innovation networks [2].

2.1.2. Innovative models of industry-education integration

Driven by digital technologies, collaborative efforts among governments, universities, enterprises, industrial parks, and industry associations have transcended traditional school-enterprise partnerships, creating new educational frameworks characterized by digital intelligence, scenario-based approaches, ecosystem integration, and global competitiveness. At its core, this model integrates educational systems, talent pipelines, industrial chains, and innovation networks to establish a deeply interconnected "education–industry–innovation" ecosystem. This approach not only addresses the demand for high-quality technical professionals in industrial digital transformation but also enables educational systems to proactively adapt to socio-economic changes, achieving dynamic equilibrium and synergistic development between talent supply and industry needs. Reforming University Talent Supply: Guided by industrial demands, universities should optimize talent cultivation structures by enhancing academic programs, curricula, teaching methodologies, practical training systems, and faculty qualifications. This strategic shift from "supply-oriented" to "demand-oriented" talent development ensures greater alignment between educational quality and industrial requirements [3].

2.2. Theoretical basis

2.2.1. Collaborative governance theory

Multiple stakeholders (government, universities, enterprises, industries, and industrial parks) share resources, assume

collective responsibilities, and jointly cultivate talent to build a digital education ecosystem. This theory emphasizes establishing effective communication mechanisms, interest coordination frameworks, and trust systems to break down barriers between entities, facilitating the free flow and efficient integration of information, technology, and capital. In the context of digital free trade ports, collaborative governance theory provides crucial theoretical support for industry-education integration. It requires governments to play policy-guiding roles and coordinate resources, universities to focus on core talent development objectives while providing enterprises with authentic industrial scenarios and practical resources, industry associations to serve as bridges and establish standards, and industrial parks to offer physical spaces and supporting services. Through forming a governance network with aligned objectives, clear responsibilities, and collaborative efficiency, all parties collectively drive the deep integration of industry and education toward systematic and standardized development [4].

2.2.2. Industrial cluster theory

Industrial agglomeration drives demand for specialized and digital talent, prompting universities to dynamically adjust their training frameworks. This theory posits that within specific regions, enterprises, institutions, and service organizations in related industries form industrial clusters through geographic concentration, generating scale effects, knowledge spillovers, and collaborative innovation. In the development of digital free trade ports, Hainan's cultural tourism and wellness industry cluster has accelerated growth leveraging policy advantages and resource endowments. Enterprises within the cluster increasingly emphasize digital technology adoption, cross-sector collaboration services, and international operations, creating an urgent need for versatile professionals with digital skills, industry expertise, and innovative capabilities. As the primary talent suppliers, universities must closely monitor industrial cluster developments and talent demand shifts. By optimizing program offerings, updating curriculum content, and strengthening practical training, they can dynamically adjust talent cultivation structures to ensure graduates precisely meet job requirements across industrial chain segments. This approach fosters a virtuous cycle between talent supply and industrial advancement, providing intellectual support for continuous cluster upgrading [5].

2.2.3. Digital competency-based theory

This framework restructures talent development systems by integrating digital skills, professional expertise, and global literacy. Guided by real-world job requirements, it establishes digital technology application capabilities as the cornerstone of talent cultivation, emphasizing the deep integration of specialized knowledge with digital tools while incorporating cross-cultural communication and international rule understanding. The theory aims to nurture innovative professionals who master industry-specific skills, adeptly apply digital technologies to solve practical problems, and possess global competitiveness. Its core innovation lies in shifting from traditional knowledge-centered education to competency-driven approaches. By defining digital competency standards for various roles and designing modular, progressive curricula with practical training systems, this model ensures alignment between talent development and industrial digital transformation needs, enabling graduates to swiftly adapt to the multifaceted competencies required by the digital economy era [6].

2.2.4. Supply-side reform theory

Optimizing educational supply factors, addressing supply-demand mismatches, and enhancing the quality and efficiency of talent provision. Originating from supply-side structural reform concepts in economics, this theory emphasizes improving supply system quality and efficiency through optimized allocation of production factors and institutional arrangements. In education, the supply-side reform approach focuses on talent cultivation at the supply end. By aligning educational resource allocation with dynamic industry demands for skilled professionals, it refines core supply elements including program structures, curriculum content, and teaching methodologies. Specifically, it aims to overcome traditional education models' limitations of rigid supply frameworks and market disconnection. Through analyzing industry trends and job competency requirements, it enables precise adjustments to talent development programs, thereby enhancing educational adaptability and effectiveness. The core objective is to resolve structural contradictions between talent supply

and industrial needs, achieve efficient utilization of educational resources, and ensure cultivated professionals not only meet quantitative requirements but also possess knowledge structures and competencies that closely align with industry demands. This approach provides robust talent support for socioeconomic development [7].

3. Development of Hainan's cultural tourism and health industry cluster and talent demand characteristics under the digital free trade port

3.1. Current status of digital transformation in industrial clusters

(1) Smart cultural tourism is advancing comprehensively

Digital transformation of scenic areas, smart navigation systems, digital cultural heritage preservation, immersive performances, and cross-border live-streaming e-commerce are experiencing rapid growth. Offshore duty-free shopping and digitalized cruise tourism operations have matured, with surging demand for cross-border cultural tourism services post-lockdown.

(2) Smart healthcare is accelerating upgrades

The Boao Lecheng International Medical Tourism Pilot Zone, tropical rainforest wellness bases, and smart senior communities are converging, fostering integrated development of "medical care + tourism + wellness". Smart health monitoring, remote diagnosis, and digitalized healthcare services are becoming widespread.

(3) The digital ecosystem is gradually maturing

Cross-border data flow policies have been implemented, with international data centers and AI computing hubs operational, providing robust computational power and data support for digital cultural tourism and wellness initiatives [8].

3.2. New characteristics of talent demand

Essential digital competencies: Proficiency in big data, AI, VR/AR, digital marketing, and smart platform operations. Core interdisciplinary competencies encompass cultural tourism, healthcare, digital technology, management, and foreign language skills. Critical international capabilities include cross-border services, intercultural communication, and understanding of global regulations. Practice-oriented innovation focuses on industrial project implementation, product innovation, and problem-solving skills.

3.3. Existing challenges in talent supply side in higher education institutions

The academic structure exhibits significant delays, with traditional disciplines dominating while emerging fields such as digital cultural tourism, smart healthcare, and cross-border services remain underdeveloped. The curriculum framework suffers from disconnection, featuring missing digital technology courses and outdated content that fails to align with industry innovations and standards. Industry-education integration remains superficial, with school-enterprise collaborations limited to internships and lectures, while enterprises lack deep involvement in the entire training process. Digital literacy remains inadequate, with both teachers and students lacking essential digital skills, compounded by scarcity of virtual simulation training and digital teaching resources. Practical competencies are insufficient due to outdated training equipment, low participation in real-world projects, and weak hands-on capabilities. Internationalization efforts are lacking, with insufficient exposure to global curricula, cross-border practices, and overseas collaborations.

4. Four innovative forms of industry-education integration under the digital free trade port

4.1. Digital-intelligent integration model: Technology empowering the entire educational process

This study leverages digital technologies to transform industry-education integration platforms, pioneering a new model

featuring “digital twin training systems, cloud-based collaborative teaching, and data-driven evaluation”. The digital twin training base collaborates with enterprises to establish VR/AR-powered virtual simulation centers for smart tourism and healthcare, replicating real-world scenarios such as scenic area operations, wellness care, and cross-border services. The cloud-based industry-education platform creates a digital collaboration ecosystem involving government, schools, enterprises, and industry stakeholders, enabling resource sharing of courses, projects, and job positions while facilitating remote instruction and online training. Through data-driven cultivation and assessment, we collect learning, training, and internship data to build digital profiles that enable precise optimization of educational programs [9].

4.2. Scenario-based Integrated model: embedded education in industrial parks

Breaking through campus boundaries, we implement the “industrial park as classroom, projects as textbooks, and job positions as mentors” model. Industrial colleges are established in the Lingshui Digital Cultural and Creative Industry Park and Boao Lecheng Medical Tourism Zone, where faculty and students reside within these parks to engage in real-world projects. Through “schools within factories” and “factories within schools”, enterprises set up production-oriented training bases on university campuses while universities establish teaching sites in enterprises, achieving alternating work-study cycles. Project-based teaching incorporates authentic initiatives such as digital upgrades for scenic areas, wellness product development, and cross-border cultural tourism planning, employing task-driven instructional methods.

4.3. Ecological integration model: Collaborative community of multiple stakeholders

Establish a “five-in-one” talent cultivation ecosystem featuring “government coordination, industrial parks as platforms, universities as primary institutions, enterprises as driving forces, and industry guidance”.

(1) Government
Formulate policies for industry-education integration and digital talent support, while building supply-demand matching platforms.

(2) Industrial parks
Consolidate corporate resources to provide practical scenarios, projects, and job opportunities.

(3) Universities
Develop training programs, deliver instruction, and cultivate graduates.

(4) Enterprises
Supply technical expertise, mentors, and projects while participating in evaluation processes.

(5) Industry
Establish standards to guide curriculum development and program optimization.

4.4. International integration model: Open education in free trade ports

Leveraging the free trade port’s cross-border data sharing and open policies, we advance “international standards, overseas collaboration, and cross-border practices”. By introducing international curricula aligned with global cultural tourism and wellness certification standards, we offer courses in cross-border services and intercultural communication. Through overseas school-enterprise partnerships, we collaborate with international cultural tourism groups and wellness institutions to jointly train students and facilitate faculty-student exchanges. Cross-border practical training programs organize student participation in international cultural tourism projects and internships at overseas wellness facilities.

5. Implementation pathways for talent supply-side reform in higher education institutions

5.1. Restructuring of professional structure: dynamic adjustment in alignment with industry trends

This study optimizes traditional programs by introducing digital specialization tracks in tourism management, hospitality management, and health services management, facilitating their transition into smart cultural tourism and smart wellness

sectors. Emerging disciplines will be strategically developed, including digital cultural tourism technology, smart wellness management, cross-border cultural tourism services, and medical tourism management. A professional cluster will be established to create interdisciplinary programs integrating "digital technology + cultural tourism + wellness + international services", aligning with industry chains. A dynamic mechanism will be implemented to jointly publish talent demand reports with industry partners and annually adjust program offerings and enrollment plans.

This study has deepened the development of professional competencies by integrating digital literacy modules into curriculum design. For instance, the Tourism Management program will incorporate big data analytics and smart tour guide system applications, while the Health Services and Management program will expand its offerings with courses on remote health monitoring and health data management. To align with international standards, we encourage programs such as Tourism Management and Hotel Management to participate in the World Tourism Organization (UNWTO) Tourism Education Quality Certification, and wellness-related programs to meet standards set by global health and wellness industry associations, thereby enhancing international recognition. Cross-disciplinary collaboration will be strengthened through joint curriculum development and collaborative research projects between digital technology programs and cultural tourism or wellness-related fields. Examples include the Digital Cultural Tourism Technology program partnering with Tourism Management to develop virtual tourism projects, and the Smart Wellness Management program collaborating with Health Services and Management to implement smart elderly care community planning initiatives.

5.2. Curriculum system iteration: Integration of digital intelligence empowerment, job courses, competitions, certification, and innovation

5.2.1. Three-tier curriculum framework

(1) Basic level

Digital literacy courses including big data, AI, digital marketing, and cross-border e-commerce.

(2) Core level

Specialized core courses such as smart scenic area operations, digital cultural innovation development, intelligent healthcare services, and cross-border cultural tourism planning.

(3) Advanced level

Courses covering international regulations, cross-cultural communication, free trade port policies, and innovation entrepreneurship.

(4) Career-course-competition-certification integration

Curriculum alignment with professional standards, incorporating 1 + X vocational skill certification programs (smart tourism, healthcare services) and industry competitions.

(5) Digital resource development

Collaborative development of online courses, virtual simulation projects, and digital textbooks through school-enterprise partnerships.

Digital and intelligent technologies are deeply integrated into all aspects of curriculum instruction. For instance, in the Smart Scenic Area Operations course, VR/AR technology simulates real-world scenic environments, allowing students to experience intelligent ticketing system operations and smart visitor flow monitoring/distribution through immersive training. The Digital Cultural Innovation Development course employs AI painting tools and 3D modeling techniques to guide students in designing virtual digital collectibles incorporating Hainan's local cultural elements. Aligning with professional competency requirements, 1 + X certification assessment components are embedded into course modules. Key knowledge points from the Health Care Certificate program (such as comprehensive elderly assessment and chronic disease management) are incorporated into practical training units within smart healthcare nursing courses. Students actively participate in national competitions like the National College Students' Red Tourism Creative Planning Competition and "Internet +" College Students' Innovation and Entrepreneurship Competition, transforming contest projects into curriculum case studies. For example, the award-winning "Smart Healthcare Community Service Platform"

project serves as a research topic for Cross-border Cultural Tourism Planning courses. Through industry-academia collaboration, digital teaching resources including the "Hainan Free Trade Port Digital Tourism Case Library" and "Smart Healthcare Virtual Simulation Training System" have been developed. The virtual simulation system comprehensively covers the entire process from health data collection and intelligent evaluation to personalized wellness plan generation, enabling students to enhance practical skills through operating virtual nursing robots and remote health monitoring devices. Additionally, an integrated online learning platform combining job training, course modules, competitions, certifications, and innovation initiatives has been established, consolidating course videos, certification materials, competition guidance resources, and entrepreneurship incubation services to achieve dynamic resource updates and personalized content delivery.

5.3. Practice teaching restructuring: Building a four-dimensional practical system

On-campus digital training programs include establishing a smart cultural tourism big data center, VR-based wellness training modules, and digital creative studios. Industry park internships involve faculty and students relocating to industrial parks to participate in project development and operational management. Corporate on-the-job training provides hands-on experience at leading cultural tourism and wellness enterprises under a dual-mentorship system. Cross-border practical projects encompass participation in live-streaming cultural tourism activities, international wellness services, and overseas digital creative initiatives.

The Smart Cultural Tourism Big Data Center integrates regional cultural tourism consumption data, scenic area operation data, and wellness resource data. Students can conduct practical training such as market segmentation analysis and tourism flow forecasting using data visualization tools. The VR wellness training cabin simulates real-life scenarios like elderly home care and rehabilitation therapy, incorporating motion capture technology to evaluate standardized nursing procedures. During on-site internship programs, faculty and students actively participate in practical projects including smart hotel room system debugging and age-friendly community renovation design, transforming classroom knowledge into problem-solving skills. In corporate internships, students undertake specific roles under dual mentorship (company mentors and academic advisors), handling cultural tourism project planning and wellness product operations, such as developing digital marketing strategies for major events and assisting institutions in optimizing smart health management systems. Cross-border practice programs leverage free trade port policies through collaborations with Southeast Asian tourism enterprises, offering virtual live tours of international travel routes and digital promotion of wellness travel products to cultivate students' cross-cultural communication skills and global perspectives [10].

5.4. Faculty team upgrade: Building a dual-qualified digital intelligence team

Digital Empowerment for Teachers: Regular training in digital skills at enterprises and industrial parks, with participation in technology R&D. Corporate Mentorship Program: Engagement of technical experts in digital cultural tourism and smart healthcare technologies as part-time instructors. School-Enterprise Hybrid Teams: Formation of interdisciplinary teams integrating teaching, research, and project implementation. International Competency Enhancement: Dispatching faculty for overseas exchanges to study international standards and models.

Specialized Competency Certification: Encourage teachers to obtain professional certifications in digital intelligence fields such as Big Data Analyst and Intelligent System Operations Engineer, integrating industry certification standards into curriculum design. Teaching Research Capacity Enhancement: Through university-industry collaborative research projects, facilitate the transformation of teachers' technical expertise into instructional case studies and develop digital intelligence teaching resource packages including virtual simulation modules and industry-specific datasets—to enhance classroom practice-oriented and cutting-edge teaching approaches. Assessment Mechanism Optimization: Establish a three-dimensional evaluation system combining "teaching competence + technical proficiency + project experience", incorporating teachers' technical breakthroughs in enterprise projects and their guidance effectiveness in digital intelligence practice initiatives into professional title evaluations and performance assessments to stimulate intrinsic motivation for

digital intelligence competency development.

5.5. Institutional Mechanism Innovation: Ensuring Reform Implementation

Multi-stakeholder collaboration mechanism: Establish an industry-education integration council to jointly build and manage industrial colleges. Benefit-sharing mechanism: Share profits from university-enterprise R&D collaborations and technology commercialization. Evaluation reform mechanism: Develop a quadrilateral assessment framework integrating "university, enterprises, industry, and international partners", with enhanced evaluation of digital competencies, practical skills, and global literacy. Policy support mechanism: Seek special policy incentives for industry-education integration and digital talent development in the free trade port zone.

Incentive and Constraint Mechanism: Establish a dedicated reward fund for digital and intelligent teaching reform initiatives, providing recognition and material incentives to outstanding faculty teams and corporate mentors in industry-education integration projects. Link students' digital practice outcomes, employment quality, and program development effectiveness, implementing early warnings and adjustments for programs failing to meet standards consecutively. Resource Sharing Mechanism: Promote collaborative development and sharing of digital teaching platforms, training bases, research facilities, and industrial data repositories between universities and enterprises. Establish cross-institutional and cross-regional alliances for high-quality educational resources to achieve efficient allocation of faculty, curricula, and equipment. Dynamic Adjustment Mechanism: Conduct regular industry talent demand surveys and forecasts, dynamically optimizing talent cultivation programs, program offerings, and industry-education collaboration models in response to free trade port policy changes and industrial trends, ensuring reforms align with market needs. Error Tolerance and Correction Mechanism: Encourage bold experimentation in digital industry-education integration innovations by tolerating non-principled errors during reforms. Establish a trial-and-error tolerance list to provide institutional safeguards for innovative practices.

6. Conclusion and prospects

The development of digital free trade ports is driving the digital and international transformation of Hainan's cultural tourism and wellness industry cluster, creating a critical demand for interdisciplinary professionals. Currently, universities face structural imbalances in talent supply. To address this, industry-education integration innovation should be prioritized to establish a comprehensive framework featuring digital intelligence, scenario-based applications, ecosystem integration, and global competitiveness. This requires implementing a "five-in-one" supply-side reform encompassing professional restructuring, curriculum iteration, practical training enhancement, faculty upgrading, and institutional innovation to achieve precise talent allocation. Hainan's local practices have demonstrated that this approach effectively resolves supply-demand mismatches and supports high-quality industrial development.

(1) Deepening digital empowerment
Promote the deep integration of AI, big data, and metaverse technologies with industry-education collaboration to innovate talent development models.

(2) Strengthening ecosystem synergy
Refine the "government-school-enterprise-industry-park" coordination mechanism to establish a flagship brand for industry-education integration in the Free Trade Port.

(3) Highlighting free trade port characteristics
Leveraging customs clearance advantages to enhance international talent cultivation and boost global competitiveness.

(4) Supporting industrial upgrading
Align with emerging cultural tourism and wellness industries, dynamically optimize supply structures, and drive high-quality development of Free Trade Port industrial clusters.

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