

Talent demand profiling and pathway analysis for academic program clusters supporting future industries in Sichuan Province

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Abstract. In 2025, Sichuan Province released the Implementation Plan for Developing Emerging Industries and Accelerating the Cultivation of Future Industries (2025–2027), identifying eight strategic directions for future industrial development, including Sixth-Generation (6G) communications and quantum technology. These emerging sectors face severe talent shortages, while the traditional higher education talent cultivation system exhibits pronounced structural mismatches with industrial demand. Using policy document analysis and logical reasoning, this study develops a multidimensional profile of talent demand from four perspectives: talent categories, knowledge structure, core competencies, and professional qualities. It further examines the supply–demand mismatch in terms of disciplinary structure, educational content, and industry–education collaboration. Based on these findings, the study proposes several strategies, including establishing interdisciplinary academic program clusters organized around industrial rather than disciplinary logic, developing modular and adaptive curricula, and deepening university–industry collaborative talent cultivation.

Keywords: future industries, talent demand profiling, academic program clusters, industry–education integration, Sichuan Province

1. Introduction

In 2025, the Sichuan Provincial Government issued the *Implementation Plan for Developing Emerging Industries and Accelerating the Cultivation of Future Industries (2025–2027)*, which identified eight strategic future industries for priority development: Sixth-Generation mobile communications (6G), quantum technology, the metaverse, frontier biotechnology, brain science and brain–computer interfaces, controllable nuclear fusion, ultra-high-speed rail transportation, and deep-earth science [1]. This policy marks Sichuan's transition from a traditional manufacturing powerhouse toward an innovation-driven province. Despite their promising prospects, these future industries are confronted with a widespread shortage of highly qualified talent. For example, 6G research requires specialists in terahertz communications; the field of controllable nuclear fusion faces a severe shortage of plasma physicists; and the development of brain–computer interfaces urgently depends on interdisciplinary professionals with expertise spanning neural engineering and computational science. The current supply of such talent falls far short of the growing demands of industrial

development. Meanwhile, the conventional higher education talent cultivation system continues to operate within the framework of single-discipline logic. Persistent challenges—including overly fragmented disciplinary specialization, slow curriculum renewal, and insufficient practical training platforms—have constrained its ability to respond effectively to emerging industrial needs. Adopting a normative research approach that combines policy document analysis with logical reasoning, this study systematically reviews policy documents and publicly available information concerning Sichuan's future industries. Building upon a comprehensive profile of talent demand, it analyzes the structural causes of the mismatch between talent supply and industrial demand, and further explores the underlying logic and practical pathways for constructing academic program clusters in higher education institutions.

2. Literature review and conceptual framework

2.1. Current state of research

The emergence of future industries as an academic concept is closely associated with the intensifying global competition in science and technology. Liu and Peng examined disciplinary development strategies for future industries from a global perspective and argued that higher education institutions must proactively restructure their disciplinary systems to meet the growing demand for interdisciplinary talent in future industries [2]. Regarding talent demand, Liu and Hu systematically reviewed the policy instruments adopted by major economies, including those in Europe and North America, for cultivating talent in future industries, highlighting their implications for policy development elsewhere [3]. Hu et al. conducted an empirical study of high-end talent demand in the regional electronic information industry using text mining techniques, providing valuable methodological insights for talent demand profiling [4].

Research on academic program cluster development has also made significant progress. Wang et al. classified the principal models and underlying logic of academic program clusters in application-oriented universities from a typological perspective [5]. Concerning industry–education integration, Liu and Xu explored curriculum reform and implementation pathways from the perspective of the mutual reinforcement between new quality productive forces and industry–education integration, offering a new theoretical lens for understanding the coordinated development of education and industry [6]. Yang investigated innovative pathways and organizational mechanisms for industry–education integration within modern industrial colleges, providing practical guidance for universities seeking to develop academic program clusters aligned with industrial needs [7]. Collectively, these studies establish a solid theoretical and practical foundation for examining academic program cluster development. However, relatively little research has systematically analyzed talent demand across an integrated regional ecosystem of multiple future industries. Consequently, a comprehensive framework for designing academic program clusters specifically oriented toward future industries remains underdeveloped.

2.2. Definition of core concepts

Future industries refer to emerging industrial sectors founded on breakthroughs in frontier technologies. Although these industries remain at the incubation stage or in the early phase of growth, they possess significant strategic importance, disruptive potential, and transformative influence. Their defining characteristics include evolving technological trajectories, business models that are still under exploration, and a severe shortage of highly specialized talent.

Talent demand profiling refers to the systematic characterization of the core attributes required of the workforce within a particular industry. Drawing on competency model theory in the field of human resource

management, this study adopts a four-dimensional analytical framework comprising: (1) talent categories, including strategic scientists, leading scientific and technological innovators, and distinguished engineers; (2) knowledge structure, encompassing disciplinary backgrounds and interdisciplinary combinations; (3) core skills, referring to key technical competencies required in specific fields; and (4) professional competencies, including innovation capability, systems thinking, engineering practice, and related professional qualities.

An academic program cluster refers to an integrated educational framework organized around a specific industrial chain or technological domain. It transcends the boundaries of individual disciplines by coordinating educational resources across schools and academic programs, thereby establishing a collaborative talent cultivation system featuring shared curricula, joint faculty development, and co-constructed teaching and research platforms. These three concepts form a coherent logical framework. The development priorities of future industries determine the categories and characteristics of talent demand; talent demand profiling provides the strategic orientation for constructing academic program clusters; and the effective operation of such clusters serves as the key mechanism for narrowing the gap between talent supply and industrial demand.

3. Talent demand profile for the eight future industries in Sichuan Province

This study employs a four-dimensional analytical framework to characterize the talent demand across Sichuan Province's eight designated future industries.

3.1. Talent categories: a polarized distribution

The talent demand across the eight future industries exhibits a "dumbbell-shaped" structure, with strong demand concentrated at both ends of the talent spectrum—strategic scientists, leading scientific and technological innovators, and distinguished engineers—while demand for mid-level talent is comparatively less pronounced. The demand at the upper end reflects the frontier nature of these industries. For example, breakthroughs in quantum computing, quantum communication, and quantum precision measurement depend heavily on profound expertise in the fundamental principles of quantum mechanics. Such world-class specialists remain extremely scarce on a global scale. Similarly, advances in plasma physics research and the engineering realization of controllable nuclear fusion require leading scientists who possess both deep theoretical knowledge and extensive experience in operating large-scale scientific facilities. Demand at the other end of the spectrum is driven by the practical requirements of industrial commercialization. As future industries move from laboratory research to market application, they require a large number of distinguished engineers who combine strong technical expertise with hands-on engineering capabilities. Tasks such as testing and deploying 6G base stations, operating and maintaining quantum computers, and conducting clinical validation of brain–computer interface devices all rely on solid engineering practice and implementation skills.

3.2. Knowledge structure: interdisciplinary integration

A defining characteristic shared by all eight future industries is their strong reliance on interdisciplinary talent. For example, the key technological directions of 6G—including terahertz communications, integrated space–air–ground networks, and intelligent metasurfaces—require expertise spanning communication engineering, electromagnetic field and microwave engineering, artificial intelligence, and computer networking. Brain science and brain–computer interfaces demand deep integration among neuroscience, materials science, computer science, and electronic engineering. The metaverse encompasses multiple interconnected technological domains, including Virtual and Augmented Reality (VR/AR), digital twins, AI-Generated Content (AIGC), blockchain, and human–computer interaction. Controllable nuclear fusion requires

coordinated expertise in plasma physics, superconducting materials, precision instrumentation, and nuclear engineering. Likewise, deep-earth science integrates geology, geotechnical engineering, sensing technologies, and automated control systems. This interdisciplinary nature indicates that universities must move beyond conventional single-discipline training models and establish curricula that facilitate cross-disciplinary integration.

3.3. Core skills: frontier technology orientation

The eight future industries exhibit a strong orientation toward cutting-edge technological competencies. Within the 6G sector, essential technical capabilities include terahertz communication technologies, intelligent metasurface design, and integrated space–air–ground networking technologies. In quantum technology, key competencies encompass quantum algorithm design, quantum error correction, and qubit manipulation and measurement. In frontier biotechnology and brain–computer interfaces, core technical skills include gene editing, neural signal decoding, implantable electrode development, and biocompatible device design. At present, these competencies remain high-threshold and low-supply capabilities worldwide. However, instructional content covering these emerging technologies is still seriously underrepresented in conventional undergraduate curricula, resulting in a significant mismatch between educational provision and industrial demand.

3.4. Professional competencies: balancing innovation and practical capability

The inherently innovative nature of future industries places exceptionally high demands on individuals' capacity for innovation. Rather than simply following standardized procedures, students must develop the ability to explore unresolved scientific and engineering challenges. Designing terahertz antenna architectures, optimizing quantum circuit compilation strategies, and developing brain signal pattern recognition algorithms are all examples of open-ended problems for which no established solutions exist. At the same time, engineering practice is equally indispensable. Future industry professionals must possess the full spectrum of capabilities required to transform theoretical concepts into practical products—from theoretical modeling and prototype development to algorithm validation and system integration. Moreover, given the rapid pace of technological iteration characteristic of future industries, the ability to learn continuously and adapt quickly, together with systems thinking that enables the integration of multidisciplinary knowledge, has become an essential competency for future industry professionals.

4. Analysis of the supply–demand mismatch between higher education talent cultivation and future industry requirements

4.1. Disciplinary structure: the conflict between overly specialized programs and interdisciplinary talent demand

The current disciplinary and academic program framework of Chinese universities is primarily based on traditional disciplinary boundaries, resulting in relatively fixed program structures and narrowly defined educational objectives. Taking the field of electronic information as an example, programs such as communication engineering, electronic information engineering, and microelectronics science and engineering each operate with independent talent cultivation plans, while their curricula remain largely separated from one another. However, when industries require professionals with expertise in areas such as terahertz communication technologies, their knowledge base must simultaneously encompass electromagnetic field

theory, semiconductor devices, signal processing, and artificial intelligence. Such a combination of competencies is difficult to naturally develop within a single academic program framework. Meanwhile, the establishment of emerging interdisciplinary programs often requires two to three years of academic review, approval procedures, and enrollment preparation, further amplifying the lag between talent cultivation and industrial demand.

4.2. Educational content: the conflict between slow curriculum renewal and rapid technological frontiers

A considerable number of university courses remain focused on classical theoretical instruction and have failed to incorporate cutting-edge developments in a timely manner. In fields related to quantum technology, for instance, frontier topics such as quantum error correction and quantum algorithm design are often introduced only at the postgraduate level, while undergraduate education remains primarily centered on fundamental concepts of quantum mechanics and the analysis of simple two-level systems. In terms of practical education, existing experimental systems are largely dominated by verification-based experiments, which cultivate the ability to "follow instructions" rather than the ability to solve unfamiliar and complex problems. The conventional training cycle of four years of undergraduate education plus two to three years of master's study (a total of six to seven years) has created a sharp contradiction with the rapid pace of technological advancement in future industries. Taking terahertz communication as an example, the technology was still largely at the laboratory validation stage around 2019, while outdoor field testing of relevant systems had already been achieved by 2023. If universities only establish specialized programs or training directions in this field in 2025, the earliest possible graduation of the first cohort of specialized professionals would be around 2029, creating a significant delay between educational supply and industrial application.

4.3. Industry–education collaboration: the conflict between insufficient cooperation depth and the need for integrated development

Most current university–enterprise collaborations remain at a relatively superficial level, including the establishment of internship bases, enterprise experts delivering guest lectures, and joint applications for industry-oriented research projects. Such approaches are insufficient to support the systematic cultivation of talent required by future industries. Students need to engage with authentic industrial contexts, confront real technological challenges, accumulate experience through collaborative problem-solving, and develop the ability to address complex problems through continuous iteration. Achieving this goal requires enterprises to participate deeply throughout the entire talent cultivation process, including curriculum co-development, access to industrial project resources, implementation of dual-mentor systems, and integrated pathways connecting internships with employment. However, incentive mechanisms encouraging enterprises to participate in talent cultivation remain underdeveloped. At the same time, university faculty generally lack sufficient experience with cutting-edge industrial practices, limiting the transformation of industry–education integration from formal collaboration into substantive cooperation.

5. Pathway design for the development of characteristic academic program clusters in universities

5.1. From disciplinary logic to industrial logic: principles for cluster formation

Traditional university program structures have been established according to disciplinary logic, which has proven effective in an era characterized by relatively stable knowledge systems. However, this approach reveals fundamental limitations when confronted with the highly interdisciplinary and integrated nature of future industries. Therefore, the primary task of academic program cluster development is to achieve a shift in organizational logic: resources should be integrated across schools and disciplines based on the technological domains and talent demand characteristics of the eight future industries. For example, a "Quantum Technology Academic Program Cluster" can be established by integrating relevant programs from schools of physics, electronic information engineering, computer science, and mathematics. Within this cluster, course modules covering quantum physics, quantum electronics, quantum algorithm design, and quantum information theory can be systematically integrated and organized. Similarly, a "Bio-Manufacturing and Neural Engineering Cluster" can be developed around frontier biotechnology and brain-computer interfaces, while a "Future Communication Technology Cluster" can be established to support the development of 6G-related industries.

5.2. Modular curriculum systems and dynamic updating mechanisms

It is recommended that universities adopt a "platform plus module" curriculum architecture. Platform courses should provide all students within the cluster with interdisciplinary foundations, covering areas such as mathematical tools, computational thinking, and innovation methodologies, thereby helping students develop transferable core competencies. Module-based courses should be designed around specific technological directions and organized into three levels: core disciplinary courses, frontier topic courses, and project-based practice courses. Meanwhile, universities should establish a rapid-response mechanism for frontier courses. For rapidly evolving fields such as 6G standard development, quantum algorithm breakthroughs, and AIGC model iterations, universities can introduce micro-specialized courses worth one to two credits. These courses can be jointly taught by university faculty and industry experts and updated dynamically each semester. Without disrupting existing credit systems, this mechanism can create institutional flexibility for timely curriculum adjustment.

5.3. Project-based learning and the integration of authentic industrial scenarios

More than 60% of professional courses within the academic program cluster should be integrated with project-based learning. Students should work in teams of three to five members to complete projects based on authentic industrial contexts. These projects may originate from enterprise technological demands, research sub-projects led by academic mentors, or real problems from disciplinary competitions. Taking a brain-computer interface cluster as an example, a student team undertaking the design of an "Attention Detection System Based on Non-Invasive EEG Signals" would need to undertake different responsibilities, including signal acquisition circuit design, EEG signal preprocessing and feature extraction, machine learning model training, and visualization interface development. Such a process naturally facilitates interdisciplinary collaboration and provides comprehensive training in engineering capabilities.

5.4. Collaborative talent cultivation mechanism through deep industry–education integration

A five-party collaborative education mechanism integrating government, industry, universities, research institutions, and application sectors should be established. At the governmental level, special funding programs should be created to support universities and leading enterprises in jointly establishing collaborative laboratories, while tax incentives should be introduced to encourage enterprises to participate in talent cultivation. At the university level, flexible faculty appointment mechanisms should be established, with a dual-mentor system consisting of academic mentors and industry mentors promoted to enhance practical orientation. At the enterprise level, companies should open access to authentic research and development projects, providing students with platforms for solving real industrial problems through practice. Some universities have already initiated exploratory practices in related fields. Supported by industrial resources, sectors such as new energy vehicles and intelligent manufacturing have begun to develop preliminary models of industry-oriented talent cultivation. These experiences can be further extended to emerging frontier fields such as chip design and satellite communications.

6. Conclusion

Based on the policy framework for the eight future industries in Sichuan Province, this study employs a four-dimensional profiling framework to analyze their core talent demand characteristics. The findings indicate that future industries demonstrate four prominent trends: polarization in talent categories, interdisciplinarity in knowledge structures, frontier orientation in core skills, and innovation-driven professional competencies. The study further reveals structural contradictions between current higher education systems and future industry requirements in three key areas: disciplinary structures, curriculum content, and industry–education collaboration. Accordingly, it proposes pathways for developing university academic program clusters oriented toward future industries. The central conclusion is that a profound mismatch exists between the talent demands of Sichuan's future industries and traditional talent supply models. Bridging this gap requires universities to shift from "disciplinary logic" to "industrial logic" and implement systematic reforms through academic program cluster development, including interdisciplinary integration, curriculum renewal, strengthened practical training, and deeper industry–education collaboration.

As a preliminary qualitative study, this research has limitations in terms of data support and quantitative precision. Future studies may employ big data mining techniques, such as recruitment text analysis and research topic modeling, to construct more refined talent demand profiles. Further empirical research should also be conducted to evaluate the effectiveness of academic program cluster development through longitudinal tracking and evidence-based assessment, thereby validating and optimizing the proposed pathways. Talent cultivation for future industries represents a systematic undertaking that requires sustained collaboration and institutional innovation among governments, universities, and industrial stakeholders. Only through continuous coordination among these actors can a new paradigm be established in which education and industrial development evolve in alignment and reinforce one another.

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