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A Study on the Adjustment Pathways of Undergraduate Specialty Structure in Shanghai HEIs from the Perspective of the Alignment between Supply and Demand of Talents

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Abstract: As China's economic center and a global metropolis, Shanghai emphasizes undergraduate specialty structure in higher education institutions (HEIs) to determine the matching efficiency between the quality of talent cultivation and industrial development. Based on the data on from 39 academic HEIs in Shanghai in 2023 and combined with the current situation of regional industrial development, this study adopts literature review, data analysis, and comparative analysis to systematically examine the characteristics of undergraduate specialty structure, their matching degree with industrial structure, and dynamic adjustment mechanisms. The findings reveal several prominent issues including excessive concentration of program offerings, significant homogenization, lagging development of emerging specialties, insufficient flexibility in adjustment and so on. These issues result in a notable mismatch between talent cultivation and the demands of three leading industries and future industries. Accordingly, this paper proposes optimization pathways from three dimensions, that is, policy coordination, industry-driven development, and self-adjustment of HEIs, to provide a reference for enhancing the capacity of higher education to serve regional high-quality economic development.

Keywords: Shanghai Higher Education Institutions, Undergraduate Specialty Structure, Industry Alignment, Dynamic Specialty Adjustment, Matching Degree Between Talent Cultivation

1. Introduction

At present, the global economy is undergoing profound transformation driven by digitalization and intelligentization, with industrial structures rapidly evolving toward higher-end and multi-faceted goals. It poses fundamental challenges to talent cultivation in higher education. During the 14th Five-Year Plan period, China's higher education has transitioned from massification to universalization. Following the achievement of large-scale expansion, the core challenge of higher education has shifted from the traditional "insufficient quantity" to "structural imbalance". On the one hand, the total number of college graduates continues to grow; on the other hand, industries and enterprises generally face the dilemma of a structural shortage of talents. This indicates a pronounced disconnect between the knowledge structures and professional competencies of the talent supply and actual market demands. The essence of this phenomenon lies in the absence of effective adaptation and agile response mechanism within the talent supply system of higher education to the evolving labor market.

The configuration of undergraduate specialties serves as the critical linkage between educational supply and industrial demand. Its rationality directly influences regional innovation-driven development and industrial transformation and upgrading. Shanghai is accelerating the construction of a modern industrial system. By 2023, the scale of its three leading industries -- integrated circuits, biomedicine, and artificial intelligence -- had reached 1.6 trillion yuan. Meanwhile, emerging industries such as the digital economy and green low-carbon development, as well as future industries including future health and future intelligence, continue to expand. However, a "time lag" and "structural gap" persist between existing specialty offerings and industrial demand, constraining the effectiveness of talent cultivation in supporting industrial development. Therefore, it is imperative to systematically explore undergraduate specialty adjustment practices from the perspective of supply-demand match.

2. Literature Review

The adjustment of specialty structure is closely related to economic and social development as well as industrial structure. This study reviews both domestic and international literature on the relationship between the specialty structure of HEIs and regional economic development, as well as research on the optimization methods.

2.1 Resource-based Correlation Between Higher Education Specialty Structure and Regional Industrial Structure

With the growing scholarly attention to the external relations of education and the interaction between higher education and regional economic development, the relationship between higher education specialty structure and regional industrial structure has gradually become a central research focus. Anderson (1998), from a macro-level perspective, examined the relationship between higher education and economic development, and then revealed the interaction between academic specialty structure and industrial structure at the micro level. Based on the dynamic two-directional interaction, he argued that specialty structure and industrial structure mutually influence and constrain one another. Similarly, Hu Dexin et al. (2016) proposed a bidirectional interaction mechanism. On the one hand, higher education promotes industrial restructuring through the provision of human capital; on the other hand, evolving industrial demand for higher talent quality compel HEIs to make adjustments accordingly. Rakesh (2010) investigated the impact of higher education specialty structure on regional industrial structure, pointing out that the former determines the type of talents cultivated, while enterprises largely rely on HEIs for skilled labor. As a result, specialty structure plays a critical role in industrial transformation, upgrading, and development. Lei Yun et al. (2017) further argued that regional industrial structure fundamentally shape university specialty configuration, which was consistent with the theory of education's external adaptability. Ji Yi er al. (2020) maintained that an effective interactive mechanism enabling higher education and industry to adapt to each other and progress jointly. However, due to the relatively loose institutional linkage, numerous practical problems emerged during the process. Wu Wenqing (2013) pointed out that the lagging and multidimensional disciplinary development has constrained HEIs' capacity to serve local economic needs. To better integrate into regional economic development, HEIs must continuously adjust their specialty offerings, refine organization, and optimize governance mechanism. Consequently, the gap between the ideal and the actual mismatch of specialty structure and regional industrial structure has become an urgent issue that requires to be addressed.

2.2 Coordination Between Higher Education Specialty Structure and Regional Industrial Structure

Wu Wenwen et al. (2015) argued that the impact of higher education on regional economic development largely depends on the level of coordination between specialty structure and industrial structure. Specialty composition of HEIs is, to some extent, a microcosm of regional industrial structure (Xu Lan et al., 2018). Regarding different specialty, Wang Chengduan and Wang Shiwei (2017), took Sichuan Province as a case to analyze the correlation between these two structures. Their findings indicated that applied disciplines exhibit higher correlation with industrial development, while the theoretical value of basic disciplines should not be overlooked. Yang Lin et al. (2015) conducted an analysis of specialty and industrial structural changes. Generally speaking, coordination degree between both declined and their changes showed "polarization" feature. This suggests significant disparities, highlighting the need for further specialty structural adjustment in higher education. From an overall perspective, due to the inherent lag in disciplinary adjustment and the influence of multiple stakeholders, the coordination between higher education and industry remains problematic. Zhang Longpeng (2012) analyzed the coupling coordination degree and found a state of mild imbalance, arguing that specialty adjustments should closely follow industrial restructuring. Zheng Xiaoxia (2020) likewise observed a widespread mismatch, with specialty adjustment generally lagging behind regional industrial development. Wang Zhihua et al. (2014), reviewing three rounds of industrial restructuring in China from 2000 to 2012, found the coordination degree between industry-related specialty structure and industry structure wass increasing year by year, while the one between manufacturing-related specialty structure and manufacturing structure was decreasing year by year. This finding was identified as a fundamental cause of the graduate unemployment and skilled labor shortages. Therefore, it is a must for higher education and industry to pursue coordinated development. Given HEIs' dependence on resources and their service-oriented role, adjustments to specialty structure should be closely aligned with regional industrial needs.

2.3 Development Pathways for Aligning Higher Education Specialty Structure and Regional Industrial Structure

The previous research explored strategies for effectively integrating higher education with regional economic development. Above all, scholars emphasized the importance of HEIs actively embedding themselves within regional economic systems and strengthening collaboration with local governments. Xu Daqi (2010) argued that HEIs should cultivate distinctive characteristics and enhance core competitiveness by proactively engaging with local economies and establishing interactive mechanisms on disciplinary construction against the backdrop. Regional economic conditions serve as a key guiding factor for optimizing programs and setting specialties. Moreover, strengthening the construction of discipline and specialty clusters has been proposed as an effective means of responding to regional economic demands. Guan Limei and Ma Junhong (2014) suggested that HEIs can better align with regional industrial clusters by developing discipline-based specialty groups, thereby enhancing their capacity to serve local industrial development. Wang Zehua (2013) further noted that specialty cluster construction can give fuller play to HEIs' advantages. HEIs should take key majors as the core and build clusters in accordance with job requirements generated from local industrial chains. Lastly, academic programs should be market-oriented and market-responsive. Drucker (2015) argued that the evaluation of university programs should be based on their degree of market alignment, with the aim of improving program quality and facilitating industrial upgrading. Hu Chidi (2009) proposed that, to achieve coordination between regional higher education development and industrial structure upgrading, the integration of disciplines, specialties, and regional industries into an institutionalized "discipline–specialty–industry" chain matters. Since regional industrial development depends on continuous technological upgrading and the support of knowledge and talent, the optimization of higher education specialty structure must be guided by market demands. At the same time, the dual nature of human agency -- both proactive and constrained -- creates complex dynamics of mutual promotion and constraints between specialty structure and industrial structure.

3.Research Methodology and Data Source

3.1 Literature review

This study employs a systematic literature review based on research recorded in the China National Knowledge Infrastructure (CNKI), Wanfang Data, and relevant government websites. Key search words include "higher education specialty structure," "alignment degree with industry" and "dynamic specialty adjustment". Through a comprehensive review of domestic and international studies, this study synthesizes existing findings and theoretical frameworks, collects data on discipline and specialty settings in Shanghai HEIs, and refers to industrial development reports as well as relevant policy documents to clarify the research foundation and data sources. It is aimed at providing theoretical support for subsequent analysis and discussion.

3.2 Data analysis

This study collects data from official platforms such as the National Higher Education Quality Monitoring Platform (2023) at the provincial level and AskCI Consulting Co., Ltd. The data is used to analyze the specialty setting of 39 academic HEIs in Shanghai in 2023, covering the number and proportion of programs across 12 disciplinary categories, as well as the extent of overlapping or repeatedly established undergraduate programs, quantitatively presenting the characteristics of the specialty structure. Furthermore, the scale of Shanghai's three leading industries is compared with the setting of related academic specialties to assess the level of industry-education alignment. Data on newly added and cancelled majors in Shanghai HEIs over the past 3 years are also analyzed to summarize the adjustment trends and provide support for problem analysis.

4. Research Findings

4.1 A diversified landscape has taken shape

Current undergraduate specialty structure adjustment in Shanghai HEIs.

As of September 2023, Shanghai has a total of 39 academic HEIs, including 4 designated under the Double First-Class University initiative and 9 under the Double First-Class Discipline initiative. By type of school, HEIs specializing in language and literature, finance and economics, and political science and law account for the largest proportion (33.33%), while those in medicine and pharmacy represent the smallest share (5.13%).

Table 1. Number and Proportion of Academic HEIs of Different Types in Shanghai

HEIs classified by type of school	Number	Proportion (%)
Comprehensive, normal, and ethnic nationality HEIs	11	28.21
Polytechnic, agriculture, and forestry HEIs	9	23.08
Medicine and pharmacy HEIs	2	5.13
Language and literature, finance and economics, and political science and Law HEIs	13	33.33
Physical culture HEIs	1	2.56
Art HEIs	3	7.69

4.2 Setting of academic programs is gradually concentrated

Undergraduate programs in Shanghai academic HEIs cover all 12 disciplinary categories, with a total of 1,627 programs. Engineering programs account for the largest share, up to 507(31.16%), followed by management (270 programs, 16.59%) and literature (210 programs, 12.91%). However, 95 basic majors and 220 specific majors are excluded, indicating areas of insufficient disciplinary coverage.

Table 2. Number and Proportion of Undergraduate Programs by Disciplinary Category

No.	Discipline	Number of Programs	Proportion (%)
1	Law	74	4.55
2	Engineering	507	31.16
3	Management	270	16.59

No.	Discipline	Number of Programs	Proportion (%)
4	Education	36	2.21
5	Economics	113	6.95
6	Science	185	11.37
7	History	8	0.49
8	Agriculture	12	0.74
9	Literature	210	12.91
10	Medicine	27	1.66
11	Art	179	11
12	Philosophy	6	0.37

4.3 Convergence of programs of overheated majors results in significant homogenization of specialty setting

For 5 specialties including English (totaling 28 programs, established by 71.79% of universities), computer science & technology (24, 61.54%), and international economics & trade (24, 61.54%), with the proportion over 7.24%, over 50% HEIs set relevant undergraduate programs.

Table 3. Specialties with the Highest Number of Undergraduate Program Offerings

No.	Specialty	Discipline	Number of Programs	Proportion (%) of HEIs setting the programs
1	English	Literature	28	71.79
2	Computer science & technology	Engineering	24	61.54
3	International economics & trade	Economics	24	61.54
4	Japanese	Literature	23	58.97
5	Business management	Management	21	53.85
Total			**120**	

4.4 Specialty adjustment is super dynamic, but programs in emerging fields are rare

Over the past three years, 207 majors were newly approved, with 320 new programs set in total. Newly established programs are mainly in fields such as data science and big data technology (18) and artificial intelligence (14). However, despite this growth, the overall scale of programs on emerging specialties remains relatively limited.

Table 4. Emerging Specialties with a Higher Number of Undergraduate Program Offerings

No.	Specialty	Discipline	Number of Programs	Proportion (%) of HEIs setting the programs

1	Data science and big data technology	Engineering	18	46.15
2	Artificial intelligence	Engineering	14	35.90
3	Intelligence manufacturing engineering	Engineering	9	23.08
4	Intelligence science and technology	Engineering	6	15.38
5	Robotics engineering	Engineering	6	15.38
6	Big data management and application	Management	6	15.38
7	Optical information science & technology	Engineering	4	10.26
8	Economic statistics	Economics	4	10.26
9	Internet and new media	Literature	4	10.26
10	Marxist theory	Law	3	7.69
11	Renewable energy materials and devices	Engineering	3	7.69
12	Rehabilitation physical therapy	Medicine	3	7.69
13	Preventive medicine	Medicine	3	7.69
14	Energy storage science and engineering	Engineering	3	7.69
15	Health services and management	Management	3	7.69
16	Arts management	Art	3	7.69
17	Financial technology	Economics	3	7.69
18	Teaching Chinese to speakers of other language	Literature	3	7.69
19	Acting	Art	3	7.69
20	Marine science and technology	acience	2	5.13

4.5 Most programs suspended enrollment are in traditional fields

As of 2023, specialties with relatively high numbers of enrollment-suspended programs include network engineering, administrative management, and exhibition economics & management. A similar pattern can be observed nationwide, where enrollment suspension takes place in traditional majors such as marketing, public services & utilities management, and business English. Since 2023, the percentage of programs stop enrollment in Shanghai is 5.93%, involving 18.51% of all majors, these two number both higher than those in other provinces.

Table 5. Comparison of undergraduate programs suspended enrollment between Shanghai and its counterpart

Categories	Shanghai	Nationwide	Beijing	Zhejiang	Jiangsu	Guangdong
Proportion of programs with suspended enrollment	5.93	3.16	3.25	2.89	2.66	2.37
Proportions of majors with suspended enrollment	18.51	44.85	12.28	15.32	17.44	13.71
Majors gotten suspended enrollment most	Network engineering	Information Management & Systems	Electronic & Information Engineering	Electronic & Information Engineering	Human Resources Management	Product Design
Majors gotten suspended enrollment second most	Administrative Management	Marketing	Information Management & Systems	Computer Science & Technology	Information Management & Systems	Network engineering
Majors gotten suspended enrollment third most	Exhibition Economics & Management	Public Services & Utilities Management	Engineering Management	Internet of Things Engineering	Public Services & Utilities Management	Internet of Things Engineering
Majors gotten suspended enrollment fourth most	Information Management & Systems	Information and Computing Science	Internet of Things Engineering	Cultural Industry Management	Optical Information Science & Technology	Business English
Majors gotten suspended enrollment fifth most	Rehabilitation Therapy	Internet of Things Engineering	marketing	Mechanical Engineering & Automation	Music performance	Broadcast & Television Journalism

4.4 Current Status and Layout of Industrial Development in Shanghai

In recent years, Shanghai's economy has maintained steady growth. In 2023, the city's gross domestic product (GDP) reached 4,721.866 billion yuan, representing a year-on-year increase of 5.0%. The value added of the tertiary sector grew by 6.0% and accounted for more than 70% of total GDP, making the tertiary sector the primary driver of economic growth. The total scale of three leading industries reached 1.6 trillion yuan and is projected to rise to 1.8 trillion yuan by 2025. Between 2020 and 2022, the integrated circuit industry recorded an average annual growth rate of 20.36%; the biopharmaceutical industry ranked first nationwide in terms of approvals for innovative drugs and medical devices; and innovation platforms of the artificial intelligence industry was accelerating laying out.

Shanghai has gradually established a modern industrial system characterized by high-end leadership and diversified coordination. This system follows a "(2+2) + (3+6) + (4+5)" framework: the "2+2" component focuses on the integration of advanced manufacturing and modern service sector, as well as industrial digitalization and green low-carbon transformation; the "3+6" centers on three leading industries -- integrated circuits, biopharmaceuticals, and artificial intelligence, together with six key industries, including electronic information and health industries; and the "4+5" encompasses four emerging industries, such as the digital economy and green low-carbon industries, and five future industries, including future health and future intelligence.

The leading industries exhibit great differences in regions. The integrated circuit industry has formed an "one-body-two-wings" layout, combining research and development in Zhangjiang with manufacturing in Lingang. The biopharmaceutical industry has advanced a "1+5+X" structure, with Zhangjiang at the core and five specialized industrial zones operating in coordination. The artificial intelligence industry has adopted a "4+X" layout, promoting collaboration across four major industrial clusters while cultivating distinctive development directions within Shanghai's "Five New Cities".

4.5 Evaluation of matching degree between academic specialty setting and industrial structure

4.5.1 Specialties related to the tertiary industry

HEIs in Shanghai offer a wide range of undergraduate programs in disciplines such as management and literature, including business administration (21 programs) and English (28 programs). These programs show a basic level of alignment with Shanghai's industrial structure with the tertiary one as the lead, providing diversified human capital support. However, shortcomings remain in terms of program specialization and distinctive positioning. Take international economics & trade as an example. Although the programs are offered at 24 HEIs, their curricula generally lack targeted content. In several HEIs, curriculum design pays insufficient attention to emerging practices associated with the development of the Shanghai Free Trade Zone, such as new trade-facilitation measures, cross-border e-commerce operating models, and new international service trade rules. As Shanghai accelerates its development into an international trade center, the demand from enterprises for talents with competencies in cross-border e-commerce platform operations, international supply chain management, and the interpretation of digital trade rules surges. Nevertheless, students trained by existing programs tend to lack adequate knowledge and skills in these areas, which weakens their competitiveness in the labor market.

Similarly, on Shanghai's path towards international financial center, the updating of finance-related curricula in HEIs has lagged behind. Some are not timely enough in incorporating frontier topics such as financial technology application, green finance innovation, and international financial risk management. For instance, course content related to the application of blockchain technology in finance, trends in carbon finance market, and the impact of changes in international financial regulatory policies on financial institutions cannot keep up with time. This phenomenon makes it difficult to meet the rapidly growing demand of the financial service sector for innovative and interdisciplinary professionals.

4.5.2 Specialties related to the manufacturing industry

HEIs in Shanghai offer a broad range of specialties under the discipline of engineering, with 507 programs covering key related fields such as machinery, materials, and electronic information. They lay a basic talent foundation for the development of Shanghai's manufacturing sector. However, structural imbalances remain evident. Traditional engineering programs account for a disproportionately large share and adjust slowly, while those aligned with emerging manufacturing needs lag behind in both scale and speed. Traditional majors such as chemical engineering & technology, and mechanical engineering & automation are widely established, whereas programs in the fields of renewable energy vehicles, intelligent manufacturing, and integrated circuit manufacturing show a clear gap between specialty setting and student enrollment of HEIs and industrial demands.

In the transition toward intelligent manufacturing, many HEIs face significant challenges. Within existing curricula, courses related to intelligent manufacturing occupy a relatively small proportion and lack systematic integration. Instruction on frontier topics such as industrial internet, intelligent factory planning, and the application of artificial intelligence remains insufficient. In training and practices, simulation equipment on smart manufacturing production lines is often outdated, limiting students' exposure to advanced industrial technologies and production models. Therefore, graduates are unable to meet enterprises' requirements for intelligent upgrading.

In addition, the development of programs such as renewable energy materials and devices is relatively slow. Although certain research achievements have been made, due to limited enrollment scale, the number of graduates every year falls far short of the strong demand generated by renewable energy vehicle industry for specialized talents in high-performance battery materials and new photovoltaic materials. It has constrained the rapid development of emerging manufacturing industries such as electric vehicles and solar photovoltaics, as well as the formation of related industrial clusters.

4.5.3 Specialties related to three leading industries

(1) Specialties related to integrated circuit industry

The specialties regarding integrated circuit industry are relatively few. As of the end of 2023, there are only four programs on the optical information science & technology, marking small scale of talent cultivation. In addition, insufficient integration between theoretical instruction and practical training persists. Theoretical coursework primarily focuses on foundational knowledge such as theoretical principles and semiconductor physics. However, practical training in chip manufacturing is ineffective because of no access to advanced equipment. Thus, students are unable to conduct hands-on training in cutting-edge fabrication technologies at laboratories on campus. For example, practices on extreme ultraviolet (EUV) lithography are almost absent. Furthermore, the versions of chip design software used in teaching are often outdated and differ significantly from the latest tools adopted by enterprises. As a result, graduates typically require a prolonged adjustment period after entering the workforce.

All in all, it significantly constrained the development of Shanghai's integrated circuit industry. Shortages in talent supply and mismatches in talent quality pose substantial challenges for enterprises in technological innovation and capacity expansion. Manufacturers represented by SMIC (Semiconductor Manufacturing International Corporation) encounter difficulties in recruiting sufficient professionals with advanced knowledge and hands-on experience when introducing cutting-edge technologies and expanding capacity, leading to slower technological upgrading. Similarly, integrated circuit design firms represented by Spreadtrum (SPRD) face extended product development cycle due to a lack of skilled personnel, which hinders their ability to deliver competitive high-performance chips in the increasingly competitive market. Consequently, these talent constraints have negatively affected the enhancement of Shanghai's industrial position and the expansion of the integrated circuit industry at both the national and global levels.

(2) Specialties related to biopharmaceutical industry

By the end of 2023, the total number of medical undergraduate programs in Shanghai HEIs stands at 27, which is relatively small. Emerging programs such as preventive medicine and rehabilitation physical therapy develop slowly, with averagely 3 programs each. In medical education, traditional medical curricula take the majority, while the integration of modern medical technologies and emerging biopharmaceutical knowledge is often neglected. For example, in programs of Traditional Chinese Medicine (TCM), instruction in classical theories and diagnostic techniques is well established, while knowledge related to modern medical imaging, biopharmaceutical technologies, and genetic testing takes just a small part in the coursebooks. For this reason, students are often unable in integrating both traditional and modern medical paradigms when addressing clinical problems. In addition, cooperation between HEIs and biopharmaceutical enterprises is insufficient in depth, and industry–academiz–research collaboration mechanisms are not yet fully complemented. Although some HEIs maintain cooperative relationships with enterprises, such collaboration is not rich in content, largely confined to student internships. Joint research projects and the co-development of innovative medical devices are rare, and opportunities are limited for students to participate directly in actual projects, keeping students away from latest technological trends and innovation dynamics.

Insufficient talent supply and relatively narrow knowledge structure constrain key technological breakthroughs and the commercialization of innovation outcomes. R&D outsourcing companies represented by WuXi AppTec are faced with low efficiency and quality while executing internationally advanced biopharmaceutical R&D projects, because of the shortage of high-level research personnel with interdisciplinary expertise and practical experience. At the meantime, as talents cultivated by HEIs lack comprehensive capability in drug target identification, drug design, and clinical trial management, innovation-driven companies such as Fosun Pharma get stuck with extended development cycle and rising costs in the process of new drug development. This has made it difficult to quickly launch innovative drug products, affecting the competitiveness of Shanghai's biopharmaceutical industry cluster and the progress of building a world-class biopharmaceutical hub.

(3) Specialties related to artificial intelligence industry

The layout of undergraduate programs related to artificial intelligence in Shanghai is not forward-looking enough. Intelligent science & technology program is set at only six HEIs. Nowadays, AI technologies continue to achieve breakthroughs in areas including deep learning algorithm optimization, the expansion of reinforcement learning application, and the exploration of novel neural network architectures, but the pace of curriculum upgrading in HEIs fail to keep up with rapid technological advances. For example, instruction on the application of the latest deep learning frameworks, such as PyTorch 2.0, is still shallow, and frontier topics such as the development of intelligent decision-making systems based on reinforcement learning are not fully included. Practical training resources are also inadequate. The lack of practice-oriented teaching platforms aligned with real-world industrial application scenarios, such as smart driving and AI-assisted medical image diagnosis, leads to limited chances of real-life practices and training. Students can only conduct simulation in labs, which is far away from actual enterprise project requirements.

These problems significantly restrict development and innovative capacity of Shanghai's AI industry. Lags in talent cultivation have left enterprises without sufficient intellectual support for AI research and application promotion. Artificial intelligence enterprises represented by SenseTime encounter difficulties in recruiting sufficient professionals who are familiar with the latest technological trends and possess practical project experience when developing new AI algorithms and expanding application scenarios. In the field of intelligent healthcare, enterprises suffer slow progress in developing AI-based diagnostic systems and personalized medical recommendation systems due to shortages of specialized talents. Consequently, these talent constraints hinder the construction of a robust AI industrial ecosystem in Shanghai, weaken the formation of core competitive advantages, and reduce the overall competitiveness at the national level.

4.5.4 Layout of future industries

Shanghai is actively planning and developing emerging industries such as the digital economy, green low-carbon development, metaverse, and intelligent terminals, as well as forward-looking industrial directions including future health, future intelligence, future energy, future materials, and future space. However, specialty setting of HEIs have shown a pronounced lag. Specifically, cutting-edge disciplines such as quantum information science, bioinformatics, and sustainable energy technologies remain extremely scarce, and the associated curricular systems and teaching resources are notably underdeveloped. In particular, Shanghai HEIs have made nearly no progress in offering programs related to frontier technologies necessary to the future intelligent industry, such as human–computer interaction, intelligent perception, and brain–computer interfaces. For example, regarding technologies including virtual reality (VR), augmented reality (AR), and digital twin technologies which is critical to the development of the metaverse, systematic curriculum design and dedicated program construction are unavailable. Under this circumstances, HEIs are unable to cultivate professional talents equipped with competencies in metaverse content creation, virtual scene construction, and interactive technology development, thereby constraining Shanghai from stepping forward.

It places Shanghai at a disadvantage in competition for future industries, making it hard to seize early opportunities. When enterprises launch projects in emerging industrial sectors, they face severe shortages of qualified talent. For instance, in the fields of future energy, HEIs are unable to supply sufficient professionals specializing in advanced energy storage technologies and hydrogen energy utilization, leaving enterprises without adequate technology and human resource for the research and development of renewable energy technologies and the construction of next-generation energy infrastructure. Consequently, deployment plans are difficult to implement effectively. These challenges not only slow the pace of development and weaken the innovative capacity of Shanghai's future industries but also hinder the upgrading of the industrial structure toward a more high-end and high-potential direction. Ultimately, this will diminish Shanghai's competitiveness and influence within the global industrial landscape.

5. Discussion

5.1 Core causes of the mismatch between the specialty structure of Shanghai HEIs and industrial demand

5.1.1 From the perspective of market

The demand feedback mechanism is underdeveloped, and the evaluation on feedback data are often significantly delayed. Disruptions in the transmission of market signals prevent HEIs from making timely and targeted adjustments to existing academic specialty structure, resulting in program planning not oriented to the future and failing to effectively anticipate market trends or implement proactive strategies in advance. Moreover, modern information technologies, including cloud computing, big data, and artificial intelligence, are not fully applied in demand feedback systems.

In addition, the depth of academia-industry collaboration remains insufficient. Enterprises play only a marginal role in the adjustment of specialty structure. In practice, cooperation between HEIs and enterprises is largely confined to internship base construction and joint industry-academia-research projects. Meanwhile, enterprises' opinions and recommendations regarding specialty adjustment cannot reach out to HEIs in a timely manner, leading to a persistent disconnect between academic offerings and market demand.

5.1.2 From the perspective of HEIs

Firstly, there is no momentum for reform given the institutional reason. Higher education administrators commonly exhibit a preference on quantity, which means most HEIs lean on establishing new programs rather than transform traditional ones, as new programs can more readily attract specific fiscal funding. Following that, more research and development fund is allocated to emerging programs, while equipment renewal and curriculum upgrading in traditional strength disciplines, such as mechanical manufacturing, appear stagnant.

Secondly, interdisciplinary integration is constrained by rigid organizational structures. The traditional faculty-based system inhibits cross-disciplinary resource integration. The "island effect" created by discipline-based evaluation systems further reinforces boundaries. For example, some faculty refuse to co-establish laboratories with others out of concern that this might cause the discipline ranking to drop.

Thirdly, talent cultivation models centered on disciplines and specialties lack diversity. When new programs are introduced, curricula are often not updated in time, resulting in outdated course content. The interdisciplinary courses only take a small share and is characterized by a "patchwork" design lacking internal coherence. The effectiveness of micro-major and dual-degree projects has yet to be fully validated. This irrational configuration of curricular systems makes it difficult to ensure training quality during specialty adjustment, thereby undermining the actual outcomes.

Fourthly, early warning mechanism and exit channel for academic specialties are ineffective, and corresponding safeguard measures are largely absent. The implementation of "flexible exit" faces substantial challenges related to resource reallocation, including faculty retraining and reassignment, student transfer and compensation, and the disposal or redeployment of physical assets. These supporting measures are to be institutionalized.

5.1.3 From perspective of government

Firstly, policy supply shows overly homogeneous. Mechanisms for classified evaluation, guidance, and construction based on the positioning and function of different HEIs are not complete. A differentiated policy on resource deployment hasn't been rolled out. In practice, a "one-size-fits-all" approach continues to dominate, with the standards of research-oriented HEIs applied across the board. This policy orientation emphasizes scholarly output over application into actual scenarios, forcing application-oriented HEIs into a state of "academic drift."

Secondly, policy responsiveness to industrial demand also exhibits significant lag. There exists a pronounced time gap between the cycle of academic specialty adjustment and the pace of industrial technological iteration. During the Shanghai Municipal "Two Sessions" in January 2025, the head of the Municipal Education Commission publicly acknowledged that "there is a time lag between program offerings and social demands, and the inertia of traditional disciplines makes it difficult to adapt to the rapid iteration of emerging industries." In terms of emerging fields such as artificial intelligence and quantum computing, the approval cycle for new academic majors is substantially longer than the average technological iteration cycle. As a result, the supply of graduates fails to meet industrial talent demand, creating a widening gap between higher education output and market needs.

Thirdly, evaluation orientation exhibits structural bias. Targeted at quality assurance, existing specialty adjustment and construction focus heavily on teaching conditions and quality. Evaluation systems place excessive emphasis on academic research results, while overlooking critical factors such as labor market feedback and industry development needs. Resource allocation and program exit is mainly decided by employment rates (for example, specialties whose graduates with employment rates below 60% for three consecutive years require refreshing), yet lack comprehensive assessment of various dimensions such as social contribution and interdisciplinary potential. This incomplete indicator system prevents HEIs from adopting a holistic perspective in specialty adjustment, resulting in fragmented and one-sided reforms. Moreover, outcome-oriented examination standards are predominantly adopted, absent of dynamic process tracking.

5.2 International Experiences and Implications of Academic Specialty Structure Adjustment

5.2.1 Key Features of Program Specialty Structure Optimization in the United States

Firstly, macro-level government coordination. In the United States, higher education macro-level governance is supported by setting higher education management institutes, such as State Higher Education Coordinating Boards. These institutes exercise oversight over academic program setting, preventing excessive duplication and homogeneous competition among HEIs and ensuring the rational allocation and efficient use of educational resources.

Secondly, market-oriented adjustment mechanisms. US HEIs closely follow the development path of labor market and workforce, enabling flexible and timely adjustments to academic programs. This responsiveness not only enhances graduates' competitiveness in the workforce but also facilitates a dynamic balance between specialty structure and evolving social needs.

Thirdly, integrated external and internal governance frameworks. Externally, state governments guide discipline construction through mechanisms such as approval system of new specialties and evaluation system of existing ones. Internally, HEIs enjoy a high degree of autonomy and established comprehensive procedures governing setting, suspension and cancellation of specialties, thereby reducing disorder and inefficiency.

Fourthly, emphasis on specialty evaluation and data-driven decision-making. Systematic and evidence-based specialty evaluations provide critical reference for government and HEIs to make decisions. In parallel, well-developed databases provide robust data support for disciplinary structure adjustment, enhancing the scientific rigor and policy rationality.

Fifthly, encouragement of innovation and an international outlook. Through strengthened support for high-tech industries, US promotes the cultivation of innovative talents to drive industrial upgrading and economic growth. At the same time, extensive international cooperation and exchange introduce international advanced technologies and management practices, further enhancing local industrial development and the continuous optimization of discipline structure.

5.2.2 Key Features of Program Specialty Structure Optimization in Germany

Firstly, close linkage to industrial structure. With advanced manufacturing, information technology, and tertiary sector take hold, specialty setting of higher education and vocational education is centering on these pillar industries. In response to the “Industry 4.0” strategy, HEIs and Universities of Applied Sciences (Fachhochschulen) have actively adjusted their specialty settings, adding new ones including intelligent manufacturing, information technology and automation. Universities of Applied Sciences is particularly practice-oriented, with many programs directly tailored to regional industrial needs, as exemplified by Munich University of Applied Sciences and its specialty setting closely related with local high-tech industries.

Secondly, high flexibility and dynamic adjustment mechanisms. German HEIs adjusts specialty settings in response to market demand and technological change. Following major breakthroughs in generative artificial intelligence in 2022, Universities of Applied Sciences quickly integrated relevant disciplinary resources and introduced new AI-related programs. This agile adjustment mechanism ensures alignment between teaching content and technological frontiers while making graduates satisfy market needs.

Thirdly, preservation and upgrading of traditional specialties. Rather than abandoning them, German institutions emphasize transformation of traditional strengths by expanding development paths and updating teaching content, to make them adaptive to modern social and industrial needs. For example, Munich University of Applied Sciences introduced new specialties such as public building engineering and construction implementation under its architecture discipline.

Fourthly, interdisciplinary integration. In response to accelerating technological convergence, German HEIs increasingly emphasize interdisciplinary majors. Some adopt “modular structures” that allow students to combine a major field with courses from other disciplines, thereby enhancing employment adaptability. This interdisciplinary approach not only broadens career pathways but also meets emerging industries’ demand for composite skilled talents.

5.2.3 Key Features of Program Specialty Structure Optimization in the United Kingdom

Firstly, strong government guidance and support. The UK government plays a pivotal role in guiding specialty structure optimization through measures including policy formulation, funding support, and tax incentives. These measures encourage collaboration and innovation among enterprises, HEIs, and research institutions, ensuring that academic specialty structure align with national economic development strategies.

Secondly, market responsiveness and flexibility. Market competition enables enterprises to adjust skill requirements in line with business development needs to improve efficiency and competitiveness. Accordingly, the education system also revises program offerings and curricula based on changing labor market conditions.

Thirdly, emphasis on innovation and technological advancement. Stronger government support for high-tech industries incentivizes enterprise-led innovation and industrial upgrading. At the same time, HEIs work actively with industry to accelerate the transfer and application of research outcomes, contributing to better industrial structure.

Fourthly, international orientation and cooperation. By actively engaging in cross-border cooperation, UK introduces advanced technologies and management experience to promote local development. Meanwhile, it prioritizes the cultivation of globally competitive talents to support long-term national economic development.

5.2.4 Key Features of Program Specialty Structure Optimization in Australia

Firstly, combination of market economy and industrial demands. Australia continuously optimizes specialty setting to reflect shifts in industrial structure and labor market demands. Specialties in the emerging fields such as computer science, information technology, and biotechnology to address workforce shortages in these areas.

Secondly, Emphasis on interdisciplinarity and comprehensive development. Specialty setting in Australia encourages interdisciplinary integration, enabling students to acquire knowledge and skills across multiple fields. This approach enhances graduates' overall competence and adaptability.

Thirdly, commitment to international alignment and educational innovation. Australian HEIs actively incorporate advanced international educational philosophies and pedagogical practices, accelerating the internationalization of higher education. Collaboration with global organizations further promotes disciplinary diversification and global engagement.

Fourthly, robust evaluation and feedback mechanisms. Regular evaluation and feedback on disciplines and specialties are critical to identify deficiencies and inform timely adjustments. These mechanisms contribute to maintaining the validity and rationality of academic specialty structure.

5.2.5 Key Features of Program Specialty Structure Optimization in Japan

Firstly, strategic alignment with economic priorities. From the mid-1950s onward, Japan took an economic development path centered on heavy and chemical industries to address structural imbalances in higher education, where humanities and social sciences were overrepresented relative to science and engineering. In response, enrollment in science and engineering was substantially expanded to meet industrial demand for technical talents.

Secondly, integration of government guidance and market regulation. The Japanese government points out clear direction through a series of policies and plans, while HEIs flexibly adjusts the specialty setting, responding actively to market needs and workforce requirements. This makes sure that specialty setting can serve social needs.

Thirdly, emphasis on innovation and international engagement. In the context of globalization and rapid technological revolution, Japanese HEIs continuously explore emerging disciplinary fields to meet diverse demands for interdisciplinary talent. By drawing on international practices and technologies, Japan supports industrial transformation and the ongoing optimization of specialty structures.

Fourthly, reliance on evaluation and data-based support. Specialty evaluation and data analysis underpin decision-making of government and HEIs, ensuring that specialty adjustments are evidence-based and policy-consistent.

5.3 Key Pathways for Building a Systematic Mechanism to Optimize and Adjust the Undergraduate Specialty Structure in Shanghai HEIs

5.3.1 Policy Coordination Mechanism: Government Guidance with Multi-Departmental Collaboration

Firstly, establishing a collaborative innovation platform across departments. On the one hand, it is essential to clarify delineation of responsibilities and coordination channels. Relevant municipal departments including Municipal Education Commission, the Development and Reform Commission should jointly establish a dedicated work group in charge of optimization and adjustment of undergraduate specialty structures in HEIs. Within this framework, the Education Commission would be responsible for overall coordination of teaching and learning activities in HEIs, supervising the whole process to guarantee educational quality. The Development and Reform Commission would provide strategic guidance based on macroeconomic planning, ensuring that HEIs serve Shanghai's urban development positioning. The Economy and Information Technology Commission would carry out in-depth research on industrial development needs, provide information on enterprise talent demands, and promote closer academia-industry alignment. The Science and Technology Commission would track frontiers of scientific and technological innovation, supporting HEIs in integrating emerging technologies into current curricula and fostering innovation-oriented talents. Regular working meetings should be organized for information sharing, joint deliberation, and coordinated decision-making, thereby improving work efficiency and coherence. On the other hand, a joint scientific deliberation mechanism should be established. For major items, such as the establishment of new majors as well as the cancellation and reorientation of existing ones, joint and evidence-based evaluations should be conducted. Cross-sector expert panels comprising education specialists, industry practitioners, and scientific researchers should be convened. During the evaluation process, multiple dimensions would be systematically assessed. For example, when reviewing proposals for setting new engineering programs, education experts would examine whether teaching resources and faculty capacity can adequately support program development; industry experts would assess future employment scale and skill requirements; and researchers would analyze technological trajectories and application prospects. Such multi-dimensional deliberation would enhance the validity of final decisions.

Secondly, improving the policy evaluation and feedback system. It is necessary to establish an evaluation model driven by big data technologies, which can be employed to collect comprehensive information concerned, including enrollment data (such as application numbers, admission scores, and student quality), employment data (graduate employment rates, industry distribution, and salary levels), teaching data (course satisfaction, teaching outcomes, and faculty allocation), and social feedback data (employer evaluations and industry recognition). Based on these datasets, a policy performance evaluation model can be developed, incorporating multi-dimensional indicators including match degree between programs and industrial demands, in order to improve talent quality and contribute to economy. Besides, regular quantitative assessments of the policy implementation effectiveness would be conducted.

Thirdly, constructing a full-process undergraduate program monitoring "profile" system. This system would establish a comprehensive indicator framework covering the entire talent cultivation process, integrating general indicators with discipline-specific ones while emphasizing both baseline quality requirements and developmental indicators. Through intelligent evaluation platforms, real-time data integration and automated analysis can be realized, enabling the establishment of a normalized monitoring and early-warning mechanism and the generation of multidimensional analytical reports. Personalized "profiles" and online diagnostic services would be helpful to provide tailored support for the characteristic development of specialty clusters within HEIs. Monitoring outcomes should be systematically applied to specialty adjustment, quality assurance, and supervisory evaluation, with a tiered implementation mechanism at national and provincial levels to ensure data reliability and scientific validity. Service items should be dynamically optimized to align with the education digitalization strategy.

Finally, forming a dynamic feedback and adjustment mechanism. Based on evaluation results, problems should be identified and fed back in time. If the cultivation goal of an undergraduate program was unable to align with market ends, which can be reflected in low employment rates and weak employer satisfaction, adjustments should be made to enrollment plans and training schemes, in particular, the specialty setting. Evaluation data can be used for resource allocation. For instance, programs with positive development prospect should receive increased financial support and take the lead in faculty recruitment, while those in opposite should experience reduced investment and be gradually restructured or phased out. Through such dynamic feedback and adjustment, a closed-loop governance mechanism encompassing policy formulation, implementation, evaluation, and revision can be established, ensuring that specialty structure remains responsive to evolving economic and social development needs.

5.3.2 Industry Demand–Driven Mechanism: Promoting Deep Integration between HEIs and Enterprises Led by Industry Demands

Firstly, building a forecasting and analysis platform on talent demands. To begin with, multiple stakeholders should get involved in data aggregation. A comprehensive big data platform for forecasting and analyzing industrial talent demands should be established through the coordinated participation of government agencies, HEIs, industry associations, and enterprises. Through cross-sector collaboration, fragmented and dispersed data sources can be consolidated into a systematic and comprehensive database. Next, advanced technologies should be applied to improve the precision. Advanced technologies including data mining, machine learning, and artificial intelligence can be used to deeply analyze integrated datasets. Multi-dimensional forecasting models should be developed based on industry categories, occupational segmentation, and skill levels. By examining the correlation between industrial development trends and talent demands through historical data and monitoring real-time market dynamics, such models can predict future demands more accurately in terms of workforce scale, professional skill requirements, and competency profiles across different industries and positions. Finally, authoritative reports are also vital to guide decision-making. Based on robust forecasting outcomes, Shanghai should regularly publish white papers and early-warning reports. The white papers would provide a comprehensive overview of current talent demand, future development trends, and catalog of high-demand disciplines, offering HEIs a clear and systematic picture of market needs. The early-warning reports would issue targeted signals for specific programs, by recommending restructuring or optimization for disciplines with talent oversupply or encouraging expanded development for programs facing urgent demands.

Secondly, promoting innovation in models of deep university–enterprise cooperation. At first, exploring industry colleges jointly built by HEIs and enterprises is recommended. The colleges should operate under a board-governed dean responsibility system. The board composed of HEIs leaders, senior enterprise executives, and industry experts would be responsible for strategic planning, defining discipline development directions, and supervising teaching quality. The dean, as the executive head, would oversee daily academic administration, faculty development, and the advancement of industry–academia–research collaboration projects. In addition, mixed-ownership models can be practiced. Under such arrangements, enterprises would participate in the establishment and operation of industry colleges with investments in capital, equipment, technology, and facilities, while universities would contribute faculty expertise and teaching and research resources. Both parties would share development outcomes and jointly bear operational risks in proportion to their respective contributions, thereby forming a more stable and mutually beneficial cooperation framework.

Thirdly, improving and expanding the modern industrial apprenticeship system. First of all, the selection and training mechanisms with dual mentors should be optimized. HEIs and enterprises should jointly formulate rigorous criteria for mentor selection. Enterprise mentors should be drawn from experienced engineers and technical experts with strong practical skills, while university mentors should be faculty members with solid knowledge foundations and extensive teaching experience. Regular training and exchange programs should be organized for both groups to enhance their instructional quality and level. Second, a comprehensive incentive mechanism for apprentice development should also be established to stimulate learning motivation and innovative capacity. Difference incentives should be provided: scholarship can be introduced to reward outstanding apprentices; clear promotion channel should also be offered, for example, high-performing apprentices may be given priority access to key enterprise projects or opportunities to assume junior technical roles; personalized career plans should be designed based on individual interests and strengths, guiding apprentices toward suitable goals.

Fourth, deepening order-based talent cultivation models. To begin with, expanding sources of training “orders” means that HEIs should actively broaden partnerships with leading enterprises and emerging firms. By participating in industry exhibitions, conducting enterprise visits, and leveraging alumni networks, HEIs can widely collect information on enterprise talent needs and establish collaborative relationships with a wider range of capable and high-potential employers. Next, order-based curricula and training processes should be refined. Curriculum systems should be aligned more closely with job requirements and career development pathways by integrating technical standards, operational procedures, and corporate culture into teaching content. Meanwhile, it is of equal importance to strengthen practical training to ensure both the duration and quality of internships and workplace-based training, allowing students to enhance hands-on skills and problem-solving abilities in authentic work environments. Throughout the training process, emphasis should also be placed on cultivating professional competencies such as teamwork, communication, and innovation. In this way, graduates will not only possess solid technical skills but also better adapt to enterprise work environments and corporate cultures, thereby improving their overall competitiveness.

5.3.3 HEIs Self-Regulating Mechanism: Optimizing Internal Governance and Innovating Dynamic Adjustment Mechanisms

Firstly, improving internal governance systems to enhance the capacity for dynamic adjustment. To begin with, HEIs in Shanghai should strengthen inner organizational structures for the dynamic adjustment of academic programs. An Academic Program Development Guidance Committee can be established, composed of HEIs leadership, heads of relevant administrative departments, deans of academic faculties, and representative senior faculty members. Serving as a consultative and decision-support body, the committee would be responsible for formulating strategic plans for program development and reviewing proposals related to the establishment of new programs, adjustment of program orientations, and cancellation of traditional programs. Such an arrangement helps ensure that decisions regarding specialty adjustment are both evidence-based and participatory. In addition, HEIs should further refine management systems and procedures. Clear standards, workflows, and accountability mechanisms should be defined for all stages of the whole process, including program establishment, adjustment, evaluation, early warning, and exit. At the same time, greater emphasis should be placed on digital governance by developing information systems that enable transparent, data-driven, and efficient management of specialty adjustment processes. This would allow HEIs to respond more promptly to both internal and external changes.

Secondly, establishing a normalized dynamic adjustment mechanism with multi-stakeholder participation. First, HEIs should institutionalize regular self-evaluation and dynamic adjustment. A routine specialty self-assessment mechanism should be established as part of a comprehensive quality monitoring and evaluation framework. By leveraging big data analysis and artificial intelligence–based evaluation tools, HEIs can conduct multidimensional assessments of faculty resources, teaching conditions, curriculum design, teaching quality, research performance, talent cultivation outcomes, and social reputation. Based on evaluation results, majors can be classified and adjusted accordingly. Well-performing programs should receive increased support to further enhance their competitiveness; programs with sound development potential but identifiable shortcomings should be required to undertake targeted improvement within a specified timeframe; and programs that no longer suit social demand or demonstrate low efficiency should be adjusted or phased out. Furthermore, a multi-stakeholder decision-support system for specialty adjustment should be developed. In addition to participation by faculty members and students, HEIs should actively solicit input from external experts, industry representatives, and alumni.

Thirdly, promoting integrated development of disciplines and specialties through interdisciplinary collaboration. To begin with, disciplinary development should serve as a driving force for program upgrading. Discipline construction plays the guiding and supporting role in leading specialty upgrading. Through the construction of high-level disciplinary platforms, the concentration of high-quality faculty, and the implementation of frontier research projects, overall disciplinary capacity can be enhanced. On this basis, disciplinary strengths can be translated into improvements in related specialties, leading to systematic upgrading in curriculum design, teaching content, and faculty composition. At the same time, HEIs should actively promote interdisciplinary integration and innovation. By breaking down traditional disciplinary and programmatic boundaries, HEIs can establish interdisciplinary research centers and laboratories to provide institutional and infrastructural support for cross-disciplinary collaboration. In terms of talent cultivation, interdisciplinary courses, dual-degree programs, and major–minor cultivation mode can be introduced to foster graduates with integrated knowledge frameworks and strong innovative capabilities.

Fourthly, innovating the development and management of micro majors. First, micro majors should be designed in close linkage to market demands, targeted at specific fields or emerging technologies with the emphasis on practical relevance. As such, they can rapidly address shortages in specialized talents and enhance alignment between HEIs training outcomes and market needs. Second, the allocation and management of teaching resources for micro majors should be optimized. To guarantee the teaching quality, HEIs should integrate high-quality faculty resources across departments and schools to form interdisciplinary teaching teams responsible for delivering curricula. Increased investment should also be directed toward teaching facilities and laboratory infrastructure to provide students with effective learning conditions. From a governance perspective, dedicated management systems should be established to regulate the application, approval, enrollment, delivery, and quality assurance of micro majors. Moreover, new models of collaboration with enterprises should be encouraged by incorporating real-world projects and case studies into teaching, thereby deepening industry–education integration and enhancing students' practical competence. Finally, a complementary and transferable relationship between micro majors and primary degree programs should be developed. Students with sufficient academic capacity should be encouraged to pursue extra micro majors' coursework, and to apply the acquired knowledge and skills into their primary disciplinary learning and practice. This integration can promote cross-disciplinary knowledge transfer, stimulate innovative thinking, and enhance students' overall academic performances.

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