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The Development History, Typology, and Current Challenges of Skill-Oriented Universities

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Abstract: Amid the global trend of the digital-intelligent economy and industrial transformation, skill-oriented universities have emerged as a crucial force driving urban innovation and development. With the evolution of new-generation information technologies, strategic emerging industries, such as artificial intelligence, integrated circuits, and intelligent connected vehicles, are witnessing exponential growth in their demand for highly skilled technical talent. However, traditional models of skills training continue to face deep-rooted challenges, including misalignment between academic disciplines and industry needs, fragmented university-enterprise collaboration in talent development, and insufficient integration of digital and intelligent technologies. By examining the development trajectory, classification, and existing issues of skill-oriented universities, this study provides a systematic analysis of their transformation and upgrading, with the aim of offering theoretical insights and practical references for cultivating world-class talent in technical and vocational fields.

Keywords: Skill-Oriented Universities; Development History; Typology; Current Challenges

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1.Introduction

In the context of the global shift toward a digital-intelligent economy and smart industrial transformation, skill-oriented universities have become a key engine for urban innovation and development. As new-generation information technology continues to advance, strategic emerging industries, including artificial intelligence, integrated circuits, and intelligent connected vehicles, are experiencing rapidly growing demand for high-level technical talent. In January 2025, the Central Committee of the Communist Party of China and the State Council issued the "Education Modernization Plan (2024 - 2035)," which, for the first time, introduced the concept of skill-oriented universities, offering a more refined classification framework for higher vocational education. The plan also proposed establishing vocational-technical programs within application-oriented undergraduate institutions, promoting integration between vocational and general education to expand students' pathways for growth and success. This reflects the increasing importance of higher vocational education. Clear definitions and classifications have laid a solid foundation for accelerating high-quality development in this sector. At the same time, skill-oriented universities must explore a distinctive path for transformation and in-depth development one that sets them apart from traditional research-oriented and application-oriented institutions through unique innovation and defining features.

As a critical link between the education system and industrial ecosystems, the transformation and upgrading of skill-oriented universities not only contribute to enhancing urban competitiveness but also carry the strategic mission of overcoming "bottleneck" technological constraints and achieving self-reliance in key sectors. Nevertheless, in practice, traditional talent training models still encounter deep-seated issues, such as the mismatch between academic programs and industry requirements, challenges in university-enterprise collaborative education, and a lack of digital and intelligent technologies. These constraints hinder the precise alignment of talent supply with industrial demands. Although current efforts have yielded notable results, development bottlenecks persist in various areas, including the slow adaptation of academic programs to industrial changes, weak university-enterprise collaboration, and inadequate integration of digital intelligence.

2.Historical Development of Skill-Oriented Universities

2.1 Evolution of Skill-Oriented Universities

The development of skill-oriented universities in China can be divided into five distinct phases. The first phase, the emergence of industrial education, spanned approximately from 1860 to 1911. The earliest form of skill-oriented institutions can be traced back to the Westernization Movement in the mid-19th century. In 1868, Zuo Zongtang and Shen Baozhen established the "Art Garden" within the Fuzhou Shipbuilding Academy, which comprised an apprentice workshop (training intermediate technicians) and a master craftsmen school (training advanced technicians). This marked China's first technical school. Its integrated model of "combining factory and school, merging work and learning" laid the practical foundation for modern skill-based education. Students participated in the production of milestone achievements such as China's first thousand-ton steamship and the first steam engine.

The second phase, the exploration of modern vocational education, lasted from 1912 to 1949. In the early 20th century, industrialist Zhang Jian founded the Textile and Dyeing Training Institute (1912) and the Women's Craft Training Institute (1914) in Nantong, Jiangsu, integrating technical training with production, a model later known as the "Nantong Model." In 1918, Huang Yanpei established the China Vocational School in Shanghai, advocating the educational philosophy of "using both hand and brain, integrating learning and practice." Through a work-study model, the school trained technicians in fields such as metalwork and carpentry, earning recognition as a pioneer in Chinese vocational education. In 1942, New Zealand friend Rewi Alley founded the Bailie Vocational School in the Shaanxi-Gansu-Ningxia Border Region, adopting a work-study approach to train mechanical maintenance and manufacturing talents, making it a key representative of vocational education in China's revolutionary base areas. Meanwhile, technical schools such as the Dalian Railway Factory Youth Technical School (1946) were established in the Northeast Liberated Area, laying the technical groundwork for New China's industrialization.

The third phase, the introduction of the Soviet model, extended from 1950 to 1977. In the 1950s, with the implementation of the First Five-Year Plan, China adopted the Soviet model to establish a technical school system. Institutions such as the Beijing Experimental Technical School (1955) were founded to train technical workers in fields like mechanical manufacturing and mining. By 1957, the country had 144 technical schools with over 60,000 students. By 1965, the number of technical schools had increased to 740, with 280,000 students, forming a backbone of technical talent supporting socialist construction.

The fourth phase, the revival and restructuring of vocational education, spanned from 1978 to 2013. The 1980 "Report on the Reform of Secondary Education Structure" proposed the policy of "promoting both general education and vocational education," leading to the gradual restoration of technical schools. The establishment of Tianjin Vocational University in 1978 marked the beginning of higher vocational education. The 1985 "Decision on the Reform of the Education System" by the Central Committee of the Communist Party of China first proposed the "establishment of a vocational education system," accelerating the development of vocational universities. By 1999, before the implementation of the college expansion policy, China had over 120 vocational universities. The promulgation of the "Vocational Education Law" in 1996 legally affirmed the status of vocational education for the first time, clarifying the developmental framework for technical schools, vocational secondary schools, and higher vocational institutions. After the college expansion in 1999, higher vocational education entered a period of rapid growth. Starting in 2005, the national "school-enterprise cooperation, work-integrated learning" model was promoted. Post-2010, WorldSkills Competition standards were incorporated into teaching outcomes, with students from technical colleges winning international awards in fields such as CNC machining and welding, facilitating the alignment of teaching standards with global benchmarks.

The fifth phase, the transition to application-oriented education and global alignment, began around 2014 and extends to 2025. The 2014 State Council "Decision on Accelerating the Development of Modern Vocational Education" proposed "guiding some undergraduate institutions to transition into application-oriented universities." By 2020, 633 application-oriented undergraduate institutions had passed industry-education integration evaluations, with Nanjing Institute of Industry Technology becoming one of the first pilot institutions for vocational undergraduate education. The 2021 revision of the "Vocational Education Law" explicitly affirmed the "equal importance" of vocational education and general education. Institutions such as Shenzhen Polytechnic University began offering vocational undergraduate programs, establishing a continuous training system spanning secondary vocational education, higher vocational education, and vocational undergraduate education. Subsequently, Shenzhen implemented the "city-industry-education consortium" system, dynamically adjusting program offerings to align with the "20+8" industrial clusters (e.g., artificial intelligence, integrated circuits), reducing the program adjustment cycle to nine months.

Looking ahead, skill-oriented universities will enter a phase of high-speed development empowered by new-quality productive forces. Post-2025, these institutions will focus on addressing "bottleneck" technologies, promoting self-reliance in skill certification standards, and leveraging virtual simulation teaching systems to enhance educational equity and skill accessibility. They will further deepen intelligent and innovative teaching models, promote the "Shenzhen Model" vocational education evaluation system, and contribute to poverty alleviation through skills development and industrial upgrading.

2.2 The Development History of Skill-Oriented Universities Abroad

The development of skill-oriented universities abroad can be divided into five main stages. The first stage, the origin of skill-oriented universities, dates back to the Industrial Revolution in the 19th century. Early models were represented by Germany's "dual system," which emphasized school-enterprise cooperation in training technical workers. Its prototype can be traced back to the medieval guild system, where apprentices were trained through a three-tier system of "apprentice, journeyman, master." The promulgation of the Handwerksordnung (Craft Trades Regulation) in 1897 established the modern dual system, where students alternate between learning in enterprises (practical training) and vocational schools (theoretical education), forming a "technology-education-enterprise" symbiotic network. By the late 19th to early 20th century, Germany's dual system had gradually matured.

The second stage, post-war reconstruction and system refinement, spanned approximately from 1950 to 1970. The enactment of the Berufsbildungsgesetz (Vocational Training Act) in 1969 marked the maturation of Germany's dual system, establishing a tripartite collaboration mechanism involving enterprises, schools, and trade associations. The act defined 450 occupational training categories and introduced the IHK (Industrie- und Handelskammer) certification system, achieving skill standardization. For example, traditional apprenticeships for fitters in the automotive industry were phased out, while training for high-skilled positions such as CNC machine operation became mainstream. By the 1970s, Germany's youth unemployment rate remained relatively low. Influenced by the Percy Report and the White Paper on Technical Education, the UK upgraded ten institutions, including the Birmingham College of Technology, to higher technical colleges in 1956, which evolved into 30 polytechnics by 1972. The Education Reform Act of 1988 granted them equal status with universities, focusing on cultivating practical talents in fields such as engineering and information technology. In the 1950s, the Truman administration promoted the development of the community college system, leading to a rapid increase in the number of community colleges and students. The "2+2" model (two years of vocational education followed by two years of academic education) became a model for mass education. For instance, California community colleges collaborated with Silicon Valley enterprises to develop semiconductor technology courses.

The third stage, globalization and deepened integration of industry and education, spanned roughly from 1980 to 2000. Germany's dual system was recognized by the European Union as a pillar of vocational education for member states. In the 1990s, countries such as China and Brazil introduced the "school-enterprise dual-subject" model. For example, some vocational colleges in China established "factories within schools," though the depth of enterprise participation remained insufficient. In 1992, Singapore's Nanyang Polytechnic pioneered the "Teaching Factory" model, embedding enterprise production lines into the campus, allowing students to directly participate in Philips' electronic component production projects. This model enhanced graduates' employability and was later promoted to ASEAN countries. In the 1990s, Australia established the "Training Packages" system, led by industry associations, which defined competency standards for over 400 occupations.

The fourth stage, digital transformation and response to new business models, spanned approximately from 2001 to 2020. The Technical University of Munich collaborated with Siemens to establish an Industry 4.0 laboratory, developing a "digital twin teaching system" that enabled students to master smart production line management skills through virtual simulation training. In 2019, the IHK added 12 emerging occupational certifications, including AI operations and maintenance and blockchain applications. In 2015, the United States enacted the STEM Education Act, promoting the introduction of courses such as drone operation and 3D printing in community colleges. Tesla partnered with Texas State Technical College to establish a "Gigafactory Training Base," where students participated in battery production line debugging, reducing the training cycle to six months. In France, the Grandes Écoles underwent reforms. In 2018, École Polytechnique partnered with Airbus Group to establish a joint research center for aerospace digital twins, where students participated in developing algorithms for predicting aircraft engine failures, with some research outcomes directly translated into corporate patents.

The fifth stage, new-quality productive forces and global governance, began around 2021 and continues to the present. In 2023, Germany launched the "Dual Vocational Education Export Initiative," establishing 15 inter-enterprise training centers in India and Mexico to export IHK certification standards. For example, BMW's Leipzig plant used this system to train local talent in high-voltage electronic control technology for new energy vehicles, enhancing local production rates. In 2024, Singapore established the world's first "Metaverse Skill Certification Platform," collaborating with NVIDIA to develop a virtual reality training system. Students can simulate the operation of chip lithography machines, reducing error rates compared to traditional teaching methods. The 2025 BRICS Skill Standard Mutual Recognition Agreement covers 28 fields, including industrial robotics and biopharmaceuticals. Shenzhen Polytechnic University collaborated with São Paulo Polytechnic in Brazil to develop a "cross-border blockchain skill passport," enabling global recognition of certificates. In 2025, the European Union launched the "Green Skills Accelerator," with the Fraunhofer Society in Germany and Delft University of Technology in the Netherlands collaborating to develop a carbon-neutral engineer certification system, covering emerging fields such as hydrogen energy storage and carbon capture technology.

3.Comparative Analysis of Skill-Oriented, Research-Oriented, and Application-Oriented Universities in Literature

Building on the review of the current state of skill-oriented universities, a comparative literature study is essential to fully understand their distinct characteristics. With the continuous deepening of educational reform, China has formally initiated the classification reform of higher education institutions, explicitly categorizing them into research-oriented, application-oriented, and skill-oriented types. This reform aims to optimize the overall structure of higher education, enabling different types of institutions to position themselves precisely and leverage their respective strengths. Simultaneously, it provides guidance for students to choose suitable development paths based on their individual aptitudes.

Research-oriented universities are centers of academic innovation and talent cultivation. As academic beacons within the higher education system, research-oriented universities have academic research and knowledge innovation as their core mission, dedicated to cultivating high-level talents with profound academic literacy and scientific research capabilities (Gu, 2025). Their discipline establishment emphasizes the coordinated development of basic disciplines, emerging disciplines, and interdisciplinary fields. Through a discipline adjustment mechanism driven by both "technological development" and "national strategic needs," they cultivate top-notch innovative talents who serve the nation's pursuit of high-level self-reliance and strength in science and technology. These institutions gather top scholars and high-quality research resources, building first-class research platforms and fostering a rich academic atmosphere. Their discipline offerings are broad and deep, demonstrating significant strength particularly in basic disciplines such as mathematics, physics, chemistry, and biology, as well as in cutting-edge interdisciplinary areas. Research-oriented universities focus on organized scientific research, deepen international exchange and cooperation, and contribute Chinese wisdom to solving common global challenges. Their graduates predominantly pursue further studies or enter research institutions, universities, and R&D departments of large enterprises, engaging in high-end scientific research and technological innovation.

Application-oriented universities serve as bridges connecting industry and cultivating practical abilities. Application-oriented universities closely align with industrial demands, aiming to cultivate application-oriented talents suited to socio-economic development, thereby acting as a bridge between education and industry. Through the precise alignment of "disciplinary specialty clusters with industrial clusters," and leveraging platforms like modern industry colleges, they promote the integration of industry, education, and research, focusing on training students' application competence in solving complex practical problems. Their specialty development revolves around the needs of the local economy and industrial development. For instance, institutions in regions with strong manufacturing sectors prioritize specialties like mechanical engineering and automation, while those in cities with thriving financial services enhance their business programs. Distinct from the "professional competence + adequate theory" model of skill-oriented universities, application-oriented universities emphasize a cultivation system of "broad theoretical foundation + application competence," focusing on the integrated development of applied research and social service (Luo et al., 2022). Graduates primarily enter the front lines of enterprises and industries, engaging in technology application, product development, production management, and other roles, injecting vitality into industrial development.

Skill-oriented universities are cradles for vocational skill training and master craftsmen. Skill-oriented universities specialize in cultivating applied talents with exquisite professional skills, serving as crucial bases for nurturing master craftsmen. They establish an integrated educational system encompassing "industry, sector, enterprise, specialty, profession," achieving precise alignment between educational resources and industrial demands through city-based industry-education consortiums and sectoral industry-education integration communities (Gu, 2025). Their specialty offerings are highly targeted, closely aligned with the requirements of specific vocational posts. For example, Culinary Arts and Nutrition programs train talents with advanced culinary skills, while Numerical Control Technology programs cultivate skilled operators of CNC equipment. Differing from the "application competence" focus of application-oriented undergraduate education, skill-oriented universities center on professional competence, constructing a "work-integrated learning" educational model that emphasizes the systematic teaching of technical and skill knowledge (Luo et al., 2022). Teaching is primarily hands-on and practical, equipped with advanced training facilities and specialized training venues that simulate real work environments. In terms of educational levels, skill-oriented universities cover a continuous training path from secondary vocational to higher vocational and vocational undergraduate education, whereas application-oriented universities extend to professional master's and doctoral levels (Luo et al., 2022). Graduates, armed with strong professional skills, directly enter related industries and enterprises, taking up front-line roles in production, manufacturing, technical services, and similar areas.

4.Current Challenges in the Development of Skill-Oriented Universities

Currently, the development of skill-oriented universities faces three major challenges. Firstly, there is significant difficulty in the dynamic adaptation of educational models to industrial demands. Most skill-oriented universities currently grapple with the challenge of a disconnect between their educational models and industry needs. Although many institutions have explored industry-university cooperation models, their curriculum design and teaching content often lag, resulting in a mismatch between the skills of graduates and job requirements. For instance, Li et al. (2025), through empirical analysis based on statistical data and job market crawler data on the alignment between talent supply from Jiangxi higher vocational colleges and enterprise demand, found a visible structural deviation in the supply and demand of skilled talents. There was a clear insufficiency in the cultivation of skilled talents for traditional producer services, as well as labor-intensive and capital-intensive manufacturing. Similarly, skill-oriented universities in Shenzhen face the issue of an oversupply of skilled talents for some traditional industries alongside an insufficient supply for high-end manufacturing and strategic emerging industries. Zheng et al. (2024) pointed out that the diversified development of higher education needs to align with the multi-level demands, multi-directional cultivation, and sustainable development of skills in a skill-based society. However, current talent cultivation models in China's higher education exhibit a degree of rigidity, making it difficult to meet rapidly changing industrial needs. On the other hand, the diversity and complexity of industrial demands also increase the difficulty of adapting educational models. The demand for skilled talents varies across regions and sectors, requiring educational models to balance common needs with personalized training requirements.

Secondly, industry-education integration often manifests as superficial collaboration and needs to evolve towards co-construction and deep innovation. From the perspective of university-enterprise cooperation, the forms of collaboration are relatively singular, primarily focusing on the establishment of internship and training bases, student employment recommendations, etc., with less depth in areas like curriculum development, teaching content updates, and scientific research collaboration. For example, the level of enterprise participation in university curriculum development is low, failing to fully leverage the practical experience and professional expertise of enterprises within the industry, leading to a disconnect between curriculum content and practical industrial applications (Yang et al., 2024). Ke and Wang (2022), taking the first batch of national modern industry colleges in the Guangdong-Hong Kong-Macao Greater Bay Area as a case study, explored the construction path of talent cultivation systems in modern industry colleges, emphasizing the educational philosophy of multi-party collaboration, the establishment of modern management structures, and the cultivation of industrial application and practical abilities. Drawing lessons from this, Shenzhen higher vocational institutions should strengthen cooperation with industries and enterprises, jointly establishing industry colleges, internship and training bases, and technological innovation platforms to propel industry-education integration towards deeper development. Through university-enterprise cooperation, jointly formulating talent cultivation schemes, developing curriculum systems, and implementing teaching processes can achieve a seamless connection between talent cultivation and enterprise needs.

Thirdly, digital-intelligent technologies pose challenges for reconstructing the teaching scenarios of skill-oriented universities. The rapid development of digital-intelligent technologies presents both opportunities and challenges for reconstructing teaching scenarios in skill-oriented universities. The opportunity lies in the ability of these technologies to provide richer teaching resources and methods. Technologies like Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI) can create immersive learning environments, enhance student interest and engagement, and promote personalized and self-directed learning. However, the challenges cannot be ignored. On one hand, the application of digital-intelligent technologies requires universities to possess corresponding hardware facilities and software platforms. Some institutions face deficiencies in digital-intelligent infrastructure, hindering the effective application of these technologies. On the other hand, the rapid iteration of digital-intelligent technologies places higher demands on teachers and students, requiring them to continuously learn and adapt to new technologies and tools. Otherwise, disparities and imbalances in technology application may arise (Hu et al., 2025; Zhang et al., 2025). In teaching scenarios empowered by digital technologies, lessons can be drawn from the experience of integrating generative AI into digital media curriculum development. Based on technology diffusion theory, a four-stage cultivation model of "technology understanding, tool mastery, creative transfer, ethical consideration" can be developed to systematically reshape the curriculum system.

Therefore, building high-level skill-oriented universities in Shenzhen urgently requires transformation, upgrading, and connotative development:

(1) Establish a dynamic program and curriculum adjustment mechanism: The program adjustment cycle in current skill-oriented universities is generally lengthy, creating a significant disconnect with the rapid technological iteration pace of "20+8" industrial clusters.

(2) Improve the industry-university collaborative education system: University-enterprise cooperation often remains at superficial stages like "order-oriented classes" and "training bases," with insufficient depth in enterprise participation. The industry college model partially addresses this issue but still exhibits tendencies towards superficiality and lack of depth.

(3) Construct a digital-intelligent empowerment development path: Integrate digital-intelligent, cross-disciplinary, and personalized learning resources. Through intelligent, modular, and collaborative learning platforms, provide high-level skill learners with flexible, diverse learning pathways and rich learning experiences.

5.Conclusion

By reviewing the development history, typological analysis, and current challenges of skill-oriented universities, we can provide theoretical support and practical insights for building highlands of skilled talent cultivation. In the process of empowering skill-oriented university development with high-quality digital-intelligent technologies, urgent focus is required in the following three areas. First, upgrade the program and curriculum mechanism of skill-oriented universities to establish a dynamic adaptation mechanism aligned with industry. Second, transform the industry college model of skill-oriented universities by deepening the industry-university collaborative education system. Finally, explore the digital-intelligent development path for skill-oriented universities to construct a new model where digital-intelligence empowers industry-education-research-application.

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Conflict of Interests

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