VTE VOCATION, TECHNOLOGY & EDUCATION

CASE STUDY

Technical skills talent development in a vocational undergraduate program: Case study of a modern communication engineering program

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ABSTRACT

The development of the digital economy represents a strategic decision aimed at addressing the demands of the current scientific and technological revolution and industrial transformation. Vocational undergraduate programs in modern communication engineering play a crucial role in developing high-level technical talent within the information and communication sector to bolster the advancement of the digital economy. This necessitates the delineation of talent development objectives, the methodical formulation of talent training schemes, investigations into synergistic models of industry-education integration, and the establishment of the professional attributes characteristic of vocational undergraduate education. Using the Modern Communication Engineering program at Shenzhen Polytechnic University as a case study, we describe a talent cultivation model and practical experiences within the field of modern communication engineering. This model encompasses the technology-driven, project-based and competency-based integration of practice and experience within a comprehensive curriculum and professional certification system and offers insights into the furtherance of high-quality vocational undergraduate education in modern communication engineering.

Key words: digital economy, information and communication vocational undergraduate program, integrated industry-education model

INTRODUCTION

As technology advances, the digital economy, which has emerged as a novel economic paradigm, is transforming the developmental patterns and societal framework of the global economy. It relies on data resources as the core elements and uses modern information networks and information communication technology. The digital economy is driven primarily by the digital transformation of various factors, which signify the future trajectory of global economic development.

China places significant emphasis on the advancement of the digital economy and has elevated it to the level of a national strategy. The report from the 20th the Communist Party of China (CPC) National Congress[1] underscored the imperative to expedite the growth of the digital economy and to foster the amalgamation of the digital and real economies. The "14th Five-Year Plan for Digital Economy Development"[2] released by the State Council identifies the digital economy as the country's primary economic structure following the agricultural and industrial economies. It also establishes the principal indicators for the development of the national digital economy during the period of the "14th Five-Year Plan", as detailed in Table 1.

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Table 1: Key indicators of digital economy development during China's 14th five-year plan period

Indicators	2020	2025
Share of digital economy's core industries' added value in GDP (%)	7.80	10
Number of active IPv6 users (in 100 million households)	4.60	8
Number of gigabit broadband users (in ten thousand households)	640.00	6000
Scale of the software and information technology services industry (in trillion yuan)	8.16	14
Industrial internet platform application penetration rate (%)	14.70	45
National online retail sales (in trillion yuan)	11.76	17
E-commerce transaction volume (in trillion yuan)	37.21	46
Registered users for online government services (in hundreds of millions)	4.00	8

The 2024 China Government Work Report[3] highlighted the need to advance innovative growth in the digital economy and establish a globally competitive digital industry cluster. In April 2024, the Ministry of Human Resources and Social Security, along with nine other departments, released the "Action Plan for Accelerating the Cultivation of Digital Talents to Support the Development of the Digital Economy (2024-2026)".[4] This plan aims to align closely with the evolving demands of digital industrialization and the digitization of industries. It outlines specific initiatives to cultivate, attract, employ, and retain digital talent in order to leverage their foundational role to bolster the digital economy. The plan seeks to hasten the emergence of high-quality productivity and enhance support for the development of the digital economy. The aforementioned policies are designed to advance the digital economy through the implementation of strategies such as technological innovation, infrastructure development, talent nurturing, and international collaboration.

The development of the information and communication industry serves as the driving force behind the digital economy. Communication networks act as both the conduits and distribution channels for data and information and are thereby laying the groundwork for the evolution of digital technology platforms and application environments. These networks constitute critical infrastructure in the digital economy. By 2023, China's 5G mobile communication industry had a total output of 1.86 trillion yuan, which marked a 29% increase compared to 2022. According to data from the Ministry of Industry and Information Technology, by the end of 2023, China had 3377 million 5G base stations. Furthermore, 5G industry applications have been incorporated into 71 major categories of the national economy, and extensive advancements have taken place within various sectors, including industry, mining, electricity, ports, and healthcare.[5–12] In the future, 6G (the more advanced next-generation mobile communication system)[13–15] will continue the transformation from connecting people and things to connecting intelligence. 6G will bring intelligence to every person, home, and business, thus leading to a new horizon of innovation and an era of true Intelligence in Everything.

KEY PRACTICES

Serve industry chain demand

The information and communication industry constitutes a comprehensive industry chain that is segmented into three primary phases: upstream, midstream, and downstream. The upstream segment encompasses communication materials, chips, modules, device design, and manufacturing. The midstream segment includes the design and manufacturing of communication equipment and terminals, and network planning and construction for communication systems, as well as the testing and certification of communication equipment and terminals. The downstream segment covers communication software design and development, business development and application in communications, and the development of applications for the digital industry.[16–20] The industry chain comprises various links, each represented by certain companies, as depicted in Figure 1.

The Modern Communication Engineering program at Shenzhen Polytechnic University (SZPU),[21–25] which is founded in the discipline of information and communication engineering, develops students in the fields of mathematics, electronic communication, and computer fundamentals. It caters to the needs of midstream and downstream positions in the new-generation information and communication industry chain. The university has adopted an integrated talent training model that combines "technology-driven, project-based learning, theoretical-practical integration, and competency-oriented instruction" in the field of information and communication with the aim of developing high-level technical professionals.

The SZPU program focuses on advancing strategic emerging industries within the realm of next-generation information and communication technology (ICT) and

Figure 1. Analysis of the next-generation information and communication industry chain.

facilitates the digital transformation of businesses. In partnership with industry leaders like Huawei, the curriculum emphasizes positions in high-end technical services, such as those of communication network engineers. The objective is to ensure students obtain a robust grounding in the fundamental theories of electronic communication and networking. Upon graduation, these individuals will be equipped to devise innovative solutions to intricate engineering challenges encountered in the design, implementation, operation, maintenance, data analysis, and application development of next-generation communication networks. Graduates will further possess the expertise to address complex issues in network operation, maintenance, and data analytics and be adept in utilizing both communication network engineering and information technology tools. They will also exhibit strong team communication abilities, a dedication to quality, self-directed learning capabilities, innovative thinking, and a global outlook, which are all essential qualities for top-tier technical professionals.

Integrated curriculum and certification system design

Based on the "technology-driven, project-based, theoretical-practical integration, and competency-based" guidance, the program major focuses on the new generation of ICT, and the university has collaborated with leading companies like Huawei to jointly design a curriculum that integrates the curriculum with certification to equip students with a high level of technical skills. Drawing upon foundational public courses, such as ideological and political education, English, and advanced mathematics, the program provides a selection of basic, core, and elective courses, which are delivered during standard academic semesters. Furthermore, three intensive practical courses have been established so that students can implement comprehensive practical projects. These are tailored to meet the requirements of roles in the next-generation information and communication field, including positions as communication network engineers, mobile communication engineers, data analysts, and business development engineers. The aim is to develop students' practical skills for these roles (Figure 2).

The foundational courses in the program incorporate mathematics and physics principles and the fundamentals of electronic communication and computer science. These mandatory courses are designed to develop students' foundational theoretical knowledge and essential skills in the field of electronic information and therefore cover areas such as mathematics, physics, electronics, circuits, computers, and communication. The specific professional foundational course offerings are detailed in Table 2.

To align with the emerging trend of intelligent and cloud network integration in the latest generation of communication networks, the professional core curriculum is divided into two-course clusters: Communication Technology and Cloud Network Integration. The curriculum comprises eight mandatory courses, which include Communication Principles and Cloud Computing Technology. The objective of these courses is to develop students' proficiencies in communication technology, operating systems, cloud computing, and artificial intelligence, as illustrated in Table 3.

Table 2: Professional foundational course curriculum

Course category	Course name	Professional abilities
Mathematics and physics	Linear algebra	Foster students' understanding and practical skills in engineering, mathematics, and physics while developing their capacity for logical analysis
	Probability theory and mathematical statistics	
	University physics and experiment	
Electronic communication	Circuit analysis	Develop students' abilities to analyze and apply electronic circuits while fostering their analytical skills in communication signals and systems
	Electronic technology	
	Signals and systems	
	Introduction to modern communication engineering	
Computer science	Fundamentals of programming	Enhance students' proficiency in applying the fundamental principles and protocols of computer networks as well as their skills in programming and debugging development
	Computer networks	
	Data structures	

Table 3: Professional core course group curriculum

Course group	Course name	Professional abilities
Communication technology	Communication principles	Enhance students' comprehension of the fundamental principles of communication systems and signal processing
	Fiber optic communication technology	
	Mobile communication technology	
	Digital signal processing	
Cloud network integration	Network operating system	Enable students to proficiently acquire the fundamental knowledge and skills associated with operating systems, cloud computing, big data, and artificial intelligence
	Cloud computing technology	
	Database technology	
	Fundamentals of artificial intelligence	

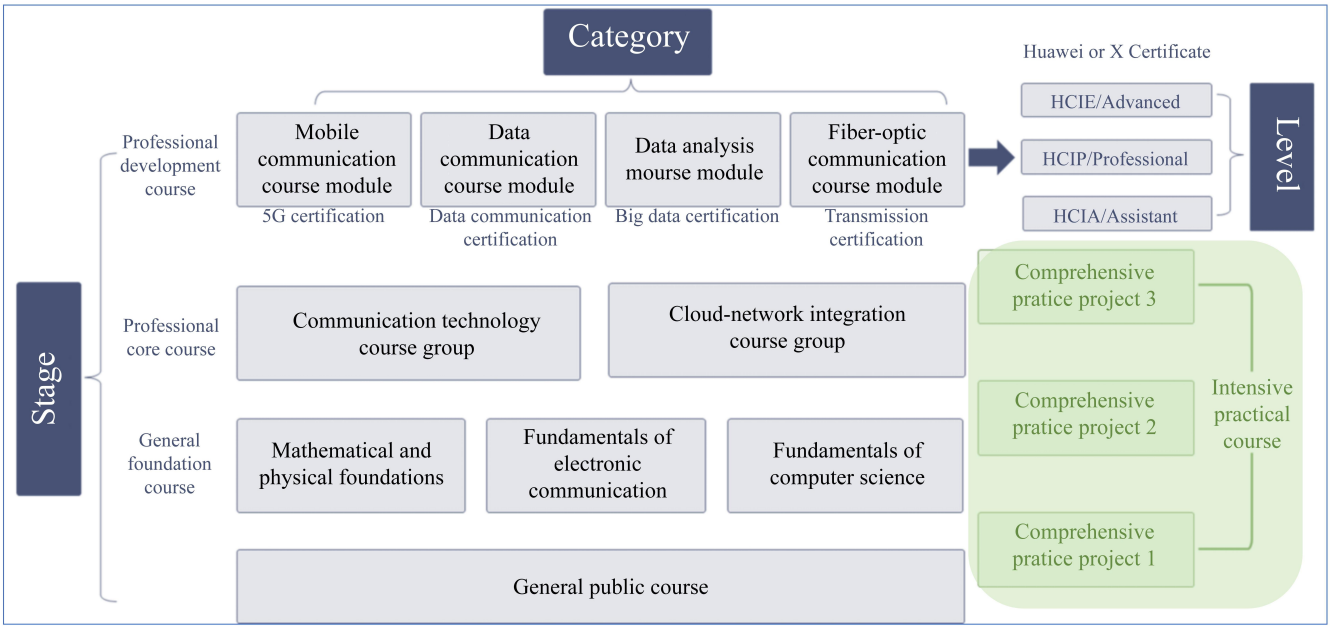

Figure 2. Curriculum system of modern communication engineering program. HCIE, Huawei Certificated lCT Expert; HCIP, Huawei Certified lCT Professional; HCIA, Huawei Certified lCT Associate; lCT, information and communication technology.

The Professional Expansion Course Module is an elective that aligns closely with the requirements of industry-leading companies, including Huawei. It encompasses four Huawei certification-oriented courses, namely, Mobile Communication, Data Communication, Data Analysis, and Transmission Engineering, with the objective of developing technical experts. In each certification course group, SZPU has established courses

on new technologies in the field of next-generation information technology, including Software-Defined Networking Technology, Optical Wave Multiplexing Technology, Cloud Development Technology, Communication Network Data Analysis, and Mobile Communication Testing and Certification, along with other cutting-edge ICT courses. These are designed to enhance students' professional skills and technical insights and thereby lay a solid foundation for their future career growth. In Table 4, we present a detailed overview of the four professional certification track course clusters.

Furthermore, the program aligns with the demands of industry, and the focused practice-oriented training approach of the "mini-semester system" has been adopted. During the first three years, students engage in a four-week intensive practical course across three mini-semesters. This course comprises three advanced and comprehensive training modules: Campus Data Communication Network Construction and Product Design, Urban Mobile Communication Network Construction and Product Development, and Digital Intelligent Industry Application Development. These modules systematically enhance students' professional competencies, job skills, and innovative capacities. These three modules and project configurations are detailed in Table 5.

Project-based course teaching implementation

The Modern Communication Engineering program places strong emphasis on practical instruction, and practical learning constitutes 55.6% of the total instructional hours. To bolster practical instruction, a sophisticated on-campus training platform and external practical teaching bases have been developed, and virtual simulation software and virtual reality platforms are used to replicate authentic engineering environments. This approach, coupled with real-world engineering case studies and the hands-on operation of equipment, facilitates the integration of theoretical knowledge and practical application, which aligns with the objectives of active teaching.[26,27] The implementation rate of training projects is 100%.

An on-campus practical teaching facility that combines hands-on instruction, societal training, industrial production, technical support, and innovation and entrepreneurship has been developed for the program.[28–30] The facility includes five specialized training labs for mobile communication, cloud computing, data communication, big data analysis in communication systems, and fundamental communication principles. These labs offer practical training exercises in areas such as 5G mobile network development, data network infrastructure, and cloud computing technologies. In collaboration with enterprises such as Huawei, Tencent, China Unicom, and Inspur Technology, 11 off-campus practical teaching bases have been established. The aim is to establish and enhance the mechanisms for collaborative development and the shared utilization of on- and off-campus teaching facilities between schools and enterprises and to develop a series of practical projects.

In line with the features of vocational education, a project-based approach, referred to as the Five-Step Teaching Method, has been adopted for the program. Using the development of a park data network as a case study, this approach includes the following steps: (1) Selection of typical application scenarios, (2) Knowledge element analysis, (3) Small projects training, (4) Enhancement of medium-sized projects, and (5) Full process design and the implementation of major projects. The complexity of the projects escalates from straightforward to intricate and encapsulates the full spectrum of project design and execution. This approach meets the demands of the role of network engineers and fosters students' competencies throughout the project lifecycle. The details are presented in Table 6.

RESULTS OF TALENT CULTIVATION

SZPU has been collaborating with Huawei since 2006 and fostered a profound and enduring partnership with the company. The university has cultivated over 400 top Huawei-certified experts, and upward of 3000 students have achieved various tiers of Huawei certification. This achievement places SZPU at the forefront of Chinese universities in this domain and represents 2% of the global total of Huawei certificated ICT expert (HCIE)-certified individuals. Program graduates have successfully executed a series of ICT projects for a range of enterprises within the ICT sector and thereby contributed significantly to the advancement of the industry and offered robust technical expertise to bolster its growth.

The project titled SZPU-Huawei Co-Cultivation of ICT Talents with Coexistence and Co-Prosperity Model won a special prize for national teaching achievement in 2018. In 2020, SZPU established China's first Huawei 5G+ digital talent cultivation base, which signified the integration of industry and education. SZPU additionally secured a total of five global special awards at the Huawei ICT Competition for two consecutive sessions in 2023-2024 and thus established itself as the institution with the most Huawei ICT Competition awards globally.

SZPU has also partnered with Huawei to create international courses on 5G, cloud computing, smart cities, and

Table 4: Professional development courses—curricula for four professional certification direction groups

Course group	Course name	Professional abilities
Data communication	Huawei data communication certification Communication network security and management Software-defined networking technology	Foster students' understanding and proficiency in Internet Protocol (IP) data communication protocols and applications as well as the management of communication network security and ensure that they stay abreast of advanced data communication technologies, including the development and management of software-defined networks
Mobile communication	Huawei 5G certification Mobile network planning and optimization Mobile communication testing and certification	Train students to excel in mobile network planning, design, optimization, testing, and certification while also equipping them with advanced technologies and skills in mobile communications
Data analysis	Huawei big data certification Communication network data analysis Cloud development technology	Train students to master the application of big data analysis tools, the analysis and application of communication network data, cloud development, and other advanced technologies and skills
Fiber optic communication	Huawei transmission certification Transmission network technology Optical wave division multiplexing technology	Instruct students on the fundamental principles of fiber optic communication, the development and utilization of transmission networks, and the latest technologies and techniques in the field of fiber optics

Table 5: Concentrated practicum modules and project configurations within the "Mini-Semester System"

Course name	Project settings
Construction and product design of park data communication network	Construction and application of an IPV4 network
	Construction and application of an IPV6 network
	Network security assurance and implementation
	Software-defined network and implementation
	Design and implementation of IP network products
Construction and product development of urban mobile communication network	Mobile network coverage planning
	Mobile base station configuration and service activation
	Mobile signaling process tracking and analysis
	Mobile network fault analysis and handling
	Mobile network product design and implementation
Digital industry application development	Intelligent manufacturing application and development
	Smart port application and development
	Smart healthcare application and development
	Smart grid application and development

additional emerging ICT technologies, which have been introduced to the nations participating in the Belt and Road Initiative. As part of international exchange platforms, such as the UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training and the UNESCO Asia-Africa Center, SZPU delivered technical training to students in over 30 nations, including Bulgaria, Germany, Malaysia, and several African countries, between 2019 and 2024. Through the Modern Communication Program, the institution has conducted upward of 40 training sessions and engaged with over 1000 participants. These efforts have significantly advanced Chinese technological and educational standards in support of the Belt and Road Initiative. SZPU has also engaged with the bridging innovation and learning in technical and vocational education and training (BILT) expert group under the World Federation of Colleges and Polytechnics and crafted the SZPU-Huawei school-enterprise collaboration case. This initiative has been disseminated to over 50 member countries within the World Federation of Colleges and Polytechnics. In 2020, it garnered the Excellence Award for School-Enterprise Cooperation from the World Federation of Colleges and Polytechnics.

CONCLUSION

The Guangdong-Hong Kong-Macao Greater Bay Area, along with Shenzhen, are global leaders in the strategic and emergent ICT industry, which requires a substantial number of high-level technical and skilled professionals. The Modern Communication Engineering program at SZPU is tailored for high-end technical service roles to support the needs of the burgeoning ICT sector. Underpinned by cutting-edge communication network

Table 6: Five-step teaching method for project-based instruction using the construction and product development course for campus data networks as an example

Number	Instructional steps	Specific content
1	Selection of typical application scenarios	Students select standard application scenarios, such as the formation of cross-regional company networks. They then analyze the network requirements specific to these scenarios and devise corresponding implementation strategies.
2	Knowledge element analysis	Students identify and categorize knowledge areas into seven key modules: Basic Operations of Network Devices, Construction of Switching Networks, Construction of Routing Networks, Network Services, Wide Area Network Connections, Network Security, and Network Management.
3	Small projects training	Using static routing configuration and implementation as an example, students learn the router packet forwarding process and the concept and configuration of routing tables to achieve proficiency in the scenarios and implementation procedures of static routing.
4	Enhancement of medium-sized projects	By carrying out medium-sized projects, including Construction of Switching Networks and Construction of Routing Networks, students learn to master the practical application of diverse technologies and to optimize network performance.
5	Full process design and the implementation of major projects	Beginning with an analysis of a company's networking needs (types of business operations, required bandwidth, and distribution of data points), students design network solutions, including the topology, required equipment, and key technologies. They then execute the project, which may include network equipment configuration, project management, acceptance, and maintenance.

technologies, the program boasts a robust partnership with Huawei. Together, the university and corporation have collaborated to develop specialized talent cultivation schemes and a comprehensive curriculum and professional certification system. This system comprises technology-driven, project-based, theoretical-practical integration, competency-based instruction, and certification *via* competitive assessments. At the same time, the program is closely aligned with the requirements of industry and has established focused, practical courses to systematically develop students' professional, job-related, and innovation skills.

To expedite the development of a contemporary vocational education system and enhance the integration of industry and education in China, SZPU *via* the Modern Communication Engineering program has collaborated with industry-leading companies, including Huawei, to jointly cultivate technical talent. These partnerships have resulted in the high-quality and advanced training of technical and skilled professionals in the information and communication sector to support the national strategy for vocational education development and contribute to the growth of the digital economy. The SZPU program in communication engineering has been borrowed and learned from hundreds of domestic and foreign universities.

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Data availability statement
Data used to support the findings of this study are available from the corresponding author upon request.

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