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DEVELOPMENT AND IMPLEMENTATION OF A DIVERSIFIED, SELF-DIRECTED TALENT DEVELOPMENT MODEL FOR COMMUNICATION ENGINEERING UNDER EMERGING ENGINEERING EDUCATION

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Abstract: With the extensive deployment of 5G and forward-looking research and development on 6G, the intelligent transformation of the communication industry is placing higher demands on engineering education. Conventional Communication Engineering programs still face fragmented curricula, delayed integration of emerging technologies, lecture-dominated instruction that limits innovative thinking, discontinuous practical training, and insufficient depth in university-industry collaboration. To address these limitations, this paper develops a four-component talent development model integrating differentiated track-based development, a modular curriculum, progressive practical training, and dynamic continuous improvement. Students are allowed to select development tracks according to their interests and career plans, while tiered competency development and track-specific course clusters provide targeted academic support. A progressive practice pathway connects basic experiments, integrated course projects, system integration, authentic industry projects, competitions, and capstone design. Teaching and employment feedback are further incorporated into a closed-loop improvement mechanism to keep the curriculum aligned with rapidly evolving technologies. The proposed framework provides an implementable reference for local universities seeking to strengthen application-oriented Communication Engineering education under Emerging Engineering Education.
Keywords: Emerging Engineering Education; Communication Engineering; Talent development; Modular curriculum; Progressive practical training

1 INTRODUCTION

With the continued implementation of "Internet Plus" initiatives and next-generation information infrastructure, together with large-scale 5G deployment, forward-looking 6G research and development, and continuing advances in the Internet of Things (IoT) and satellite communications, the communication industry is accelerating toward intelligent and converged development. These changes have introduced new challenges and higher expectations for talent development in Communication Engineering [1-2]. In response to the new wave of technological and industrial transformation, a series of national policy documents, including the New Generation Artificial Intelligence Development Plan and the 14th Five-Year Plan for Digital Economy Development, have called for stronger development of high-level interdisciplinary engineering professionals and deeper reform of engineering education under Emerging Engineering Education (EEE). Outcomes-based education (OBE) has consequently become an important orientation for engineering education reform, requiring universities to place students at the center, align programs closely with industrial needs, and continuously improve their talent development systems.
Under conditions of rapid technological iteration, conventional education centered on the transmission of disciplinary knowledge has gradually exposed several limitations [3]. Typical problems include insufficient differentiation among specialization tracks, weak modular curriculum design, and delayed incorporation of emerging technologies. Universities in different countries have explored diversified reform models for Communication Engineering education. Representative examples include interdisciplinary communications-and-AI curricula at the Massachusetts Institute of Technology, intensive enterprise internship arrangements at RWTH Aachen University, and integrated undergraduate-to-doctoral pathways with dual university-industry mentoring at Tsinghua University [4]. However, such models depend heavily on strong research capacity and high-quality industrial resources. Local universities often face constraints in platform conditions, industry engagement, and student preparedness [5-6]. Developing an adaptable, implementable, and sustainable talent development system that matches the positioning of local universities is therefore a pressing task in current engineering education reform.

2 CURRENT STATUS AND EXISTING PROBLEMS IN COMMUNICATION ENGINEERING TALENT DEVELOPMENT

2.1 Fragmented Curriculum and Outdated Content

A coherent curriculum is a necessary foundation for assuring the quality of talent development. Although curriculum reform has been steadily advanced at many universities, several prominent problems remain. Courses are often offered as isolated modules, with limited integration across knowledge areas, making it difficult for students to form a holistic understanding of communication systems. An excessive proportion of general courses can compress the time available for professional practice, while emerging interdisciplinary courses are introduced slowly and teaching materials and laboratory content are not updated in a timely manner. Verification-oriented experiments remain dominant, whereas integrated engineering training is insufficient, resulting in a mismatch between teaching content and actual industrial needs. In addition, the positioning of different specialization tracks is often unclear and their competency objectives are insufficiently differentiated, preventing differentiated development from being implemented effectively. Cross-module curriculum integration and stronger comprehensive practical teaching are therefore essential for helping students build a complete professional knowledge structure and improve their engineering practice capabilities.

2.2 Lecture-Dominated Instruction and Insufficient Development of Innovation Competencies

Conventional classroom instruction is not sufficient to cultivate innovative engineering competencies. Teaching is still dominated by one-way theoretical lectures, while project-based inquiry and discussion-oriented learning are used inadequately, and complete research-practice training processes are often absent. Students therefore spend long periods receiving theoretical knowledge passively, with limited opportunities to design independent solutions, troubleshoot equipment, or participate in multidisciplinary integrated training. Educational provision at the intersections of communications, artificial intelligence, and big data is also insufficient. As a result, students may struggle to develop systematic engineering thinking and lack the integrated problem-solving capability required for complex engineering scenarios. Diversifying classroom methods and introducing end-to-end research training and interdisciplinary projects can stimulate independent inquiry, strengthen systematic engineering thinking, and improve the ability to address complex engineering problems.

2.3 Incomplete Practical Training System and Limited University-Industry Collaboration

A well-designed practical teaching system is a major support for strengthening hands-on engineering capability. Existing practical activities are still dominated by basic verification experiments and have not yet formed a complete progressive pathway from basic experiments to integrated design, industry projects, and capstone design. Laboratory equipment on campus may be outdated, while off-campus collaboration is often limited to short visits or observational internships. Authentic enterprise projects, jointly developed university-industry courses, and teaching by industry mentors cover only a limited proportion of students. Enterprise participation in talent development is consequently insufficient, and students lack end-to-end project experience, which weakens both engineering implementation and project coordination capabilities. Universities therefore need to construct a progressive practical training chain and deepen university-industry collaboration so that students can obtain more complete project experience and steadily improve their engineering practice and project management capabilities.

2.4 Single-Dimensional Assessment and Imbalanced Educational Orientation

A diversified assessment system is essential for high-quality talent development, yet weaknesses remain in both student evaluation and faculty development. Course assessment is commonly centered on final written examinations and laboratory reports, with insufficient tracking of the learning process and limited evaluation of innovative outcomes. Achievements in discipline competitions, research projects, and industry practice are often excluded from comprehensive assessment. A multidimensional evaluation mechanism that simultaneously considers innovation capability, teamwork, and integrated engineering competency has not yet been fully established, making it difficult to motivate sustained participation in scientific and technological innovation. At the same time, some instructors have limited front-line engineering experience, reducing their ability to organize effective project-based and inquiry-oriented teaching. Establishing a process-oriented, diversified assessment mechanism while strengthening the engineering practice experience of faculty can therefore improve student motivation for innovation activities and enhance the effectiveness of professional talent development.

3 DEVELOPMENT OF A DIVERSIFIED, SELF-DIRECTED TALENT DEVELOPMENT MODEL UNDER EMERGING ENGINEERING EDUCATION

3.1 Overall Design of the Development Model

As shown in Figure 1, the proposed talent development framework contains four core layers: differentiated track-based development, a modular curriculum, progressive practical training, and dynamic optimization and improvement. At the first layer, four representative tracks are established: wireless communications, optical communications, IP networking technologies, and telecom service development. Students select a track according to their interests and career plans, enabling a shift from uniform education toward more targeted development. At the second layer, professional courses are reorganized into four modules: general foundations, professional core, track extension, and practice and innovation. These modules progress hierarchically and support one another, maintaining a common professional foundation while enabling differentiated development across tracks. At the third layer, students progress through three stages - basic cognition, integrated engineering, and innovative research and development - moving from foundational experiments in the early years to industry projects and innovation competitions in later years, with engineering capability as the organizing thread. At the fourth layer, periodic revisions of the program are driven by achievement evaluation of educational objectives and multi-channel teaching feedback so that training content can remain synchronized with industrial technology.

The four components are logically connected and mutually reinforcing, forming a stable and complete implementation pathway. Differentiated track-based development provides the orientation for curriculum reconstruction; the modular curriculum establishes the theoretical foundation required for progressive practical training; practical activities validate the appropriateness of track positioning and course design; and the dynamic improvement mechanism integrates feedback from the complete teaching process to support closed-loop optimization of the overall system.

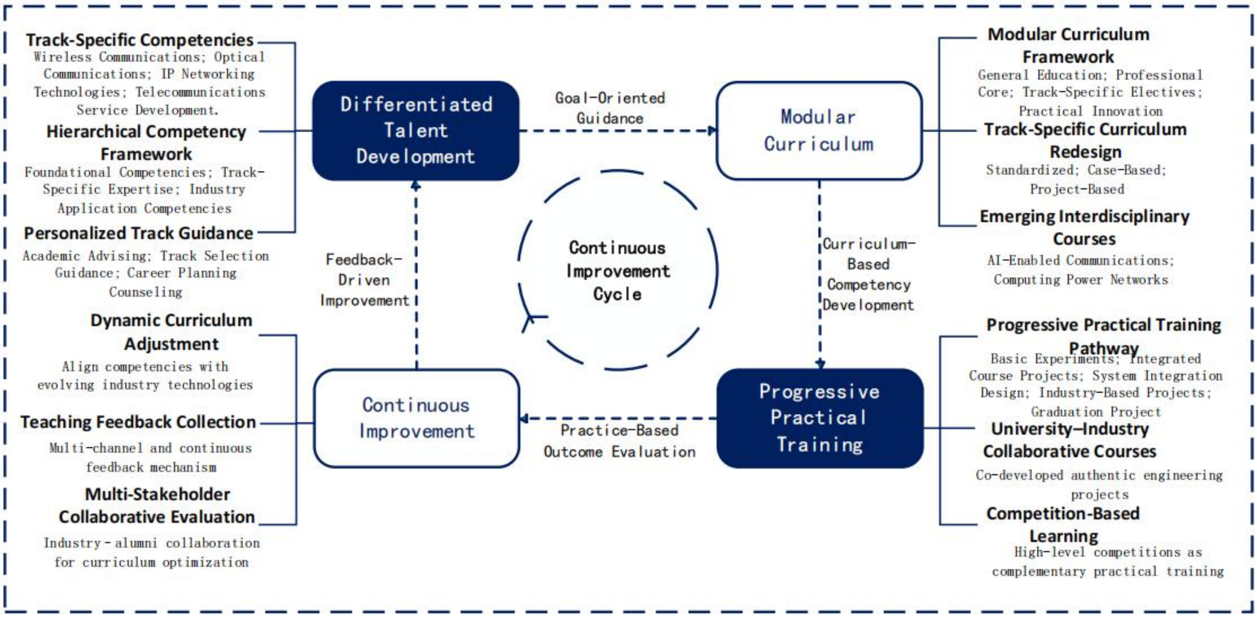

Figure 1 Talent Development Framework for Communication Engineering

3.2 Differentiated Track-Based Development System

The communication industry is rapidly shifting from a traditional pipeline-transmission model toward intelligent and converged service ecosystems, and the deep integration of artificial intelligence with communication technologies has become a mainstream trend. As occupational structures change, homogeneous and single-track educational models can no longer match the differentiated competency requirements of specialized technical domains. Accordingly, this framework combines mainstream employment positions and research directions in communications with the institutional strengths of local universities to establish four distinctive development tracks. Students are allowed to complete track selection independently according to their interests and long-term career plans.

The wireless communications track focuses on key 5G/6G technologies, wireless transmission, channel modeling, and mobile network organization. It is oriented toward wireless-technology positions at network operators and communication equipment enterprises, with particular emphasis on mobile communication system design and optimization. The optical communications track covers optical-fiber transmission, optical-device technologies, and high-speed optical network construction. It responds to the needs of backbone transmission networks and optical-network engineering and maintenance positions, highlighting practical abilities in optical-network planning, deployment, and troubleshooting. The IP networking technology track emphasizes network architecture, routing and switching, cybersecurity, and intelligent networking. It is designed for network operations and maintenance and system integration positions in public-sector and enterprise environments, with attention to network architecture design, security-policy configuration, and intelligent network management. The telecom service development track integrates communication technology with software development, focusing on digital telecom platforms and communication service-system development. It is aligned with intelligent communication software development positions and emphasizes software engineering thinking and the ability to implement and integrate service systems.

On the basis of track selection, the pathway for tiered and differentiated competency development is further refined. Foundational courses such as advanced mathematics, university physics, computer programming, and engineering ethics develop common foundational competencies and provide the shared knowledge base required by all tracks. Track-specific technical characteristics are then used to construct differentiated clusters of core courses and supporting practical training modules, enabling students to deepen their expertise in specialized technical domains and build systematic track-specific competencies. Authentic engineering projects from enterprises, case discussions based on typical industry scenarios, and field internships in front-line positions further guide students in applying professional theories flexibly and gradually developing the capability to transform disciplinary knowledge into solutions for practical engineering problems.

A corresponding differentiated guidance mechanism is also established. It includes introductory lectures on the discipline and career planning before track selection, continuous academic mentoring after selection, and regular activities such as lectures by industry experts and enterprise open days. These measures help students clarify the positioning of each track and optimize their learning pathways. By respecting individual differences and patterns of student development, the system seeks to strengthen job readiness and sustainable professional growth in Communication Engineering.

3.3 Reconstruction of a Modular Integrated Curriculum

To address the repetition, insufficient application orientation, and weak alignment with industrial needs that are common in existing professional courses, the curriculum is reconstructed according to the principles of modular integration, tiered progression, and industry-education collaboration.

First, a four-level modular curriculum is developed in the sequence of general foundation, professional core, track extension, and practice and innovation. Course levels are clearly differentiated and the function and articulation of each module are specified. The general foundation module strengthens common competencies in mathematics, computing, and information science. The professional core module integrates major courses such as principles of communications, network technologies, and signal processing to reduce duplicated instruction. The track extension module establishes differentiated course clusters for wireless communications, optical communications, the Internet of Things, and network and information security. The practice and innovation module connects laboratory work, course design, integrated training, and capstone design. Credit recognition and content articulation across modules enable organic curriculum integration and improve system coherence, continuity, and openness. Second, track-oriented courses are reconstructed in standardized, case-based, and project-based forms through the development of teaching case repositories and deeper university-industry joint education. Case repositories are built around 5G/6G, the Industrial Internet, smart cities, and cybersecurity, while authentic enterprise tasks are introduced so that students complete solution design, system implementation, and optimization in realistic contexts. This approach strengthens both engineering practice and alignment with industrial requirements. Finally, selected emerging interdisciplinary modules are introduced, including AI + Communications, Computing Power Networks (CPNs), and Big Data and Intelligent Network Management. By integrating artificial intelligence, cloud computing, big data, and communication networks, these courses broaden students' knowledge structures, strengthen integrated application and innovation capabilities, and improve the forward-looking character of the curriculum.

Through these measures, a modular curriculum with a solid foundation, clearly defined professional core, and distinctive development tracks can be established to support the education of high-caliber, application-oriented Communication Engineering professionals.

3.4 Progressive and Tiered Practical Teaching System

To overcome insufficient completeness, limited depth, and weak articulation among practical teaching activities, a new practical teaching system is reconstructed around hierarchical progression, project-driven learning, and multidimensional content integration. The system proceeds through basic experimental training, integrated course experiments, system integration design, authentic industry project practice, and capstone design. It follows a step-by-step development logic and enables students to participate deeply in project implementation, thereby creating stronger conditions for the development of practical capability.

Basic experimental training emphasizes individual skills and standardized operating procedures, establishing a solid hands-on foundation. Integrated course experiments combine related knowledge within a specific course and cultivate initial comprehensive application capability. System integration design requires students to design solutions for complete systems and perform integrated commissioning, thereby strengthening systems thinking and engineering implementation. In parallel, Communication + AI practical content is explored through projects such as machine-learning-based channel modeling, deep-learning-based signal recognition, and intelligent traffic optimization. These projects serve as advanced supplements to conventional practice and expand integrated application and innovation capability. Students are also encouraged to participate in high-level competitions, including electronic design contests, innovation and entrepreneurship competitions, and the Datang Cup, using competition-driven learning to provide more intensive practical training beyond the regular progressive pathway [7].

At the stages of authentic enterprise projects and capstone design, university-industry practice platforms are further strengthened. Representative engineering project courses are jointly developed with established enterprises for scenarios such as 5G network optimization, optical network deployment, IP network security, and communication service development. Enterprise project tasks are embedded into core courses so that progressive training moves gradually from campus-based simulation to authentic industrial environments. In these settings, students conduct requirements analysis, collaborate in teams, implement projects, and optimize solutions. Building on prior training, they are expected to independently investigate and design solutions for relatively complex engineering problems, thereby improving the depth of engineering practice and their ability to deliver complete engineering outcomes [8].

A progressive and tiered practical teaching system thus creates a pathway from basic to integrated tasks, from campus to enterprise environments, and from structured training to innovation. This pathway can effectively improve students' engineering application capability, problem-solving capability, and adaptability to professional positions.

3.5 Data-Driven Closed-Loop Mechanism for Continuous Improvement

A long-term optimization mechanism is established to support continuous improvement of talent development. Student learning data, practical achievements, employment feedback from enterprises, and changes in industrial technologies are used to periodically adjust development tracks, course content, and practical activities. During this process, the program closely follows large-scale 5G commercialization, early-stage 6G research, and the deep integration of artificial intelligence with the communication industry. Particular attention is paid to the evolution of communication networks from data transmission toward intent-driven, goal-oriented networking and from centralized management toward decentralized autonomous management and control, including the emerging concept of agentic communication networks in which autonomous AI agents participate in network decision-making and coordination. Routine teaching-data collection focuses on achievement levels in interdisciplinary AI + Communication Engineering course clusters and incorporates qualitative and quantitative feedback related to future network requirements such as low-carbon operation, energy efficiency, and low-cost automated operations and maintenance, thereby improving the timeliness and forward-looking nature of teaching evaluation.

Frontier content in 6G, AI-enabled communications, and intelligent networking is incorporated in a timely manner, while outdated content is removed to form a closed-loop educational process of development, implementation, feedback, and optimization. This mechanism helps ensure that the talent development model remains aligned with the pace of industrial change under Emerging Engineering Education. Because vertical-industry applications are characterized by highly complex and strongly differentiated scenarios, the four tracks - wireless communications, optical communications, IP networking technologies, and telecom service development - are adjusted when necessary. Conventional machine-learning and deep-learning techniques are incorporated into professional course content, while programming and artificial intelligence courses introduce the concepts and applications of neural networks, large language models (LLMs), and related AI algorithms. These measures improve articulation between established professional knowledge and rapidly emerging technologies.

To ensure stable operation of the closed-loop mechanism, continuous improvement also focuses on long-term iteration of the practical teaching system and educational resources. In response to the requirements of vertical industries for intelligent control and algorithm validation, practical teaching can make use of existing university-industry joint laboratories and modern communication network training platforms. Intelligent communication simulation modules, open AI algorithm-validation environments, and integrated training projects for intelligent network control are progressively incorporated into syllabus revision. The program regularly consolidates outcomes from student innovation competitions, capstone projects, and university-industry projects to drive routine updates of modular course clusters. In this way, structural mismatches between the supply of graduates and actual industrial demand can be reduced, while the talent development system remains responsive to the evolution of Emerging Engineering Education and the communication industry.

4 CONCLUSION

Against the background of Emerging Engineering Education and rapid development of the digital economy, talent development in Communication Engineering must actively adapt to industrial transformation and upgrading. Based on the requirements of Emerging Engineering Education and the intelligent development trend of the communication industry, this paper develops a diversified, self-directed talent development model characterized by autonomous track selection, modular curriculum support, progressive practical empowerment, and dynamic iterative optimization. The framework addresses major limitations of conventional Communication Engineering education, including homogeneous development pathways, fragmented curricula, and insufficient depth of practical training. Deepening industry-education integration and research-education synergy while continuously improving the talent development system is a systematic undertaking that requires coordinated participation by faculty, universities, and industrial partners. Such coordination can support the development of high-caliber Communication Engineering professionals with innovation awareness, strong engineering practice capabilities, and an international perspective.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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