

Innovation and Teaching Reform of the Talent Training Mode in Integrated Circuit Science and Engineering under the Background of New Engineering: A Case Study of North University of China

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Abstract: The construction of new engineering disciplines is an important component of the national talent cultivation strategy, and the reform of talent cultivation mode in integrated circuits, as an emerging field of national strategy, has significant practical significance. This article takes the School of Semiconductors and Physics at North University of China as a case study to explore the construction and practice of an integrated circuit talent training system based on the “one quality, three abilities” framework. The research constructs a core framework for talent cultivation consisting of “one quality” (patriotism and engineering ethics) and “three abilities” (professional foundation and self-learning ability, engineering practice and system integration ability, interdisciplinary collaborative innovation ability). The research results show that through the leading position of North University of China in the Shanxi Semiconductor Industry Technology Innovation Alliance, this system has achieved precise alignment between talent cultivation and industry demand. The diversified collaborative education mechanism (including professional teachers, research supervisors, teaching administrators, and counselors) covers the entire talent cultivation cycle, effectively enhancing students’ engineering literacy and innovation ability. This study provides a valuable reform path for the cultivation of integrated circuit talents in the context of new engineering disciplines in local universities.

Keywords: New Engineering; Integrated Circuit Science and Engineering; One quality, three abilities; North University of China

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1. Introduction

The new engineering education initiative has emerged as a cornerstone of China’s national talent cultivation strategy, aiming to address the mismatch between traditional engineering education and emerging industry

demands ^[1]. Among all engineering disciplines, integrated circuit (IC) science and engineering holds particularly strategic importance, as China's semiconductor industry faces a severe talent shortage despite massive state investment. Traditional IC talent training models have struggled with curriculum rigidity, outdated content, and weak industry-education collaboration, limiting graduates' ability to meet evolving technological challenges.

Local universities face additional constraints in implementing new engineering reforms. With large student cohorts, elevated student-teacher ratios, and insufficient engineering experience among young faculty members, they encounter significant challenges in delivering practical, industry-aligned education. Meanwhile, established institutions like Tsinghua University and Peking University have established dedicated IC colleges, yet their models may not be directly transferable to regional universities with different resource endowments ^[2]. Therefore, developing adaptable reform pathways that fit local university conditions represents a critical research priority.

However, existing literature on new engineering education predominantly focuses on theoretical frameworks or elite university cases. There remains insufficient documentation on how regional universities operationalize these concepts through concrete collaborative mechanisms. This paper addresses this gap by examining North University of China's implementation of a diversified collaborative education mechanism involving professional faculty, research supervisors, teaching administrators, and counselors throughout the talent cultivation process. The study contributes empirical evidence to the understanding of new engineering reforms and offers a replicable model for similar institutions nationwide.

2. Current status of cultivating innovative talents in integrated circuit science and engineering

The IC science and engineering major is the cornerstone of the national science and technology strategy, and the core dilemma of current talent cultivation lies in the "disconnect between industry and education." Although universities continue to expand their enrollment scale, the update of the curriculum system lags behind the rapid iteration of the chip industry, resulting in a significant mismatch between the structure of talent supply and the urgent demand for high-end engineering practical abilities in the industry ^[3].

Faced with challenges, the industry is promoting a deep transformation from "theoretical teaching" to "industry education integration." By strengthening the construction of joint laboratories between universities and top enterprises, introducing real process data and tool flows, and implementing mentorship-based project practical training, the education system attempts to break down traditional disciplinary barriers, aiming to shorten the ability transformation cycle for students from "campus textbooks" to "production line engineering."

According to data, the demand for talent in China's integrated circuit industry is projected to reach approximately 766,500 by 2023, yet the annual number of graduates from related majors at universities remains below 30,000 ^[4]. This continuously widening gap in high-level and innovative talents seriously affects the development path for related industries to climb up the value chain. The traditional engineering talent training model is no longer suitable for the rapid iteration, interdisciplinary integration, and strong practical requirements of the integrated circuit industry.

The construction of new engineering disciplines emphasizes student development as the center, industry demand as the guide, and innovation ability cultivation as the main line, providing key conceptual guidance

for systematic reform of the integrated circuit talent training system. Therefore, exploring teaching reform in the integrated circuit major at local universities, represented by North University of China, possesses both practical urgency and important strategic significance.

Taking North University of China as a case study, its talent cultivation system has progressed beyond the initial exploration stage, entering a phase of systematic construction and effectiveness, supported by physical platforms, guided by deep industry-education integration, and oriented toward high-quality employment. The university has sent over 2,000 graduates to leading domestic enterprises such as the Aerospace Science and Technology Corporation and China Electronics Technology Group Corporation, many of whom have grown into technical backbones.

3. Necessity of cultivating innovative talents in integrated circuit science and engineering

Integrated circuits, as a national strategic, fundamental, and leading industry, are known as the “food of modern industry” and the “core area of great power competition.” At present, there is a serious talent gap in China’s integrated circuit industry. It is expected that the demand for talent will reach 300,000 by 2025, and the talent gap will reach 300,000 to 500,000 by 2030. The total scale of industry talent is expected to reach around 790,000 by 2024, with a talent gap of around 230,000. At the same time, with the explosive growth in demand for high-performance chips in emerging fields such as artificial intelligence, quantum technology, and new energy, the traditional talent training model has problems such as outdated curriculum systems, outdated content, and poor school-enterprise cooperation^[5]. Only 12–19% of graduates majoring in integrated circuits enter related industries, which is difficult to meet the development needs of strategic emerging industries.

Compared with traditional top universities, local universities face practical constraints such as large student sizes, high student-teacher ratios, and insufficient engineering experience among young teachers. Therefore, it is necessary to establish a “one quality, three abilities” talent cultivation system and a “one platform, four spaces” school-enterprise collaboration mechanism to achieve precise alignment between talent cultivation and industry demand. As the “First University of the People’s Armed Forces,” North University of China has provided replicable reform experience for local universities through its leading position in the Shanxi Semiconductor Industry Technology Innovation Alliance.

Integrated circuits are a strategic tool for safeguarding national security. In the context of international decoupling and supply interruption, achieving high-level technological self-reliance and self-improvement must rely on independent innovation. Building an independent and controllable integrated circuit industry ecosystem from the source and cultivating a specialized talent team covering the entire industry chain is the only way to accelerate the breakthrough of key technological bottlenecks. Strengthening the cultivation of integrated circuit talents is of great significance in supporting the transformation of the industry from “mid to low-end manufacturing” to “high-end creation,” which helps the country occupy a more advantageous position in global competition and effectively supports the high-quality development of the integrated circuit industry.

4. Issues of cultivating innovative talents in integrated circuit science and engineering

The integrated circuit science and engineering major is the cornerstone of the national scientific and technological innovation system, but there is a significant structural contradiction between the education supply and the demand for rapid industrial development in the current process of cultivating high-level innovative talents ^[6]. The following provides an in-depth analysis of the key issues facing the cultivation of innovative talents from five dimensions:

Integrated circuit technology follows Moore's Law and has a very fast iteration speed in the industry, covering cutting-edge fields such as advanced process technology (such as 3 nm/2 nm), system in package (SiP), and heterogeneous computing architecture. However, the construction of the curriculum system in universities usually has a long lag period. The existing teaching content often overly focuses on classical microelectronics physics and basic device theory, while lacking sufficient coverage depth for key technologies that support the core competitiveness of the contemporary chip industry, such as high-speed interface design, low-power circuit optimization, high-performance analog ICs, and backend physical design of large-scale digital circuits (EDA toolflow). This kind of teaching content configuration that emphasizes foundation over cutting-edge often leads students to face the dilemma of "not applying what they have learned" when exposed to real industrial projects, requiring a long period of on-the-job training to truly get started.

The integration of industry and education is the core of talent cultivation in integrated circuits, but currently it still remains at a shallow level of school-enterprise cooperation in most universities. True innovative talents need to be honed in complex engineering environments, that is, by encountering real process parameters, yield data, and complex EDA environments to discover and solve problems ^[7]. At present, university training platforms mostly rely on simplified teaching software or simulation experiments that are detached from actual production, lacking deep integration with real production lines (Fab) in the industry. Students in school laboratories are only exposed to idealized mathematical models, while engineering boundary conditions such as process deviations (PVT variations) and signal integrity analysis, which are crucial in chip design, are often overlooked in teaching. This makes students extremely lacking in the ability to make technical trade-offs and engineering decisions in complex environments.

As chip design enters the post-Moore era, the traditional boundaries of microelectronics have been broken. The innovation of high-performance integrated circuits not only relies on circuit design, but also heavily on the underlying material physics, packaging thermodynamics, advanced manufacturing processes, and the collaborative design of upper-level computer architecture and compilers ^[8]. The current talent cultivation model often has obvious disciplinary barriers, and students are too single in their choice of major, lacking horizontal knowledge integration ability. For example, there is a lack of architects who understand the underlying mechanisms of physics, as well as a lack of underlying hardware engineers who understand compiler performance optimization. Although this in-depth exploration of a single discipline ensures a solid foundation, it suppresses students' perspective on chip design issues from a system-level perspective, making it difficult to cultivate top composite talents who can coordinate software and hardware, and integrate manufacturing and design.

The evaluation system in academia tends to lean towards paper publication and theoretical derivation to a certain extent, while engineering innovation is often accompanied by high-risk, long-term trial-and-error

processes. The current assessment indicators are too quantitative, and the oriented “short-term performance” assessment makes students more inclined to choose theoretical topics that are easy to produce results when participating in scientific research projects, rather than challenging complex process optimization, yield improvement, or low-level EDA tool development, which are extremely difficult but have core value for the industry. This evaluation orientation leads to innovative talents developing a thinking inertia of avoiding great difficulty engineering challenges during the student stage, weakening their innovative impulse and courage to undertake “0–1” technological breakthroughs in future work.

The growth of talents in the integrated circuit industry has a typical “accumulation and gradual development” characteristic, from a graduate to a senior engineer who can independently undertake core module design or process optimization, usually requiring 5 to 10 years of deep cultivation. However, the current fierce industrial competition environment has made the mobility of talents extremely high [9]. Some graduates who master core technology are subject to the temptation of high-wage industries such as the Internet and finance, and move to non-core fields prematurely, resulting in an insufficient talent retention rate in the industry. In the process of training, universities not only lack long-term guidance for students’ career development, but also lack mechanisms for jointly building talent incentives and sustainable development with the industry. This has led to a serious gap in the already scarce graduates of integrated circuit majors after entering the industry, not only affecting the talent pool construction of enterprises, but also causing the loss of intellectual resources accumulated by the country in key core technology fields for a long time.

5. Exploration of innovative talent cultivation in integrated circuit science and engineering at North University of China

The Integrated Circuit Science and Engineering major at North University of China has addressed the systemic challenges of industry disconnection, lack of practice, and single evaluation in current talent cultivation. With the concept of “new engineering” as a guiding principle, it has reconstructed the top-level design of talent cultivation and formed a new paradigm of education that runs through the entire process of value shaping, knowledge imparting, and ability cultivation. The primary pillar of this program is the “one quality, three abilities” characteristic talent training system. By internalizing ideological and political education and engineering ethics into professional teaching, schools not only guide students to establish the ideal belief of serving the country through science and technology, but also strengthen their systematic design ability, complex engineering practice ability, and interdisciplinary collaborative innovation ability through systematic curriculum modules, while enhancing their professional basic theory. This collaborative education model of “all staff, all-round, and whole process” breaks through the limitations of traditional single discipline training, ensuring that students can have solid insight into underlying physical mechanisms and sharp engineering system decision-making skills when facing the rapid technological iteration in the post Moore era, thus truly realizing the transformation from “knowledge reserve” to “technological innovation” talents.

To break the bottleneck of “shallow” cooperation between schools and enterprises, North University of China has innovatively built an innovative ecosystem of deep integration of industry, academia and research. The school takes the lead in establishing the Shanxi Semiconductor Industry Technology Innovation Alliance and uses it as a digital link for resource integration. By creating four core spaces, including undergraduate internship and training rooms, graduate joint training rooms, school enterprise joint teaching and research

rooms, and school enterprise collaborative innovation rooms, a closed-loop operation mechanism is established. Deeply tied with industry leaders such as Taiyuan Semiconductor Vision and Guoke Semiconductor, the introduction of real EDA toolchains, mainstream manufacturing process data, and pilot equipment ensures a high degree of consistency between educational scenarios and industrial production environments. This model goes beyond the loose and temporary cooperation between schools and enterprises in the past, establishing a sustainable collaboration mechanism of “talent co-education, process co management, achievement sharing, and responsibility sharing,” enabling enterprises to deeply participate in the entire process of curriculum system updates, talent quality evaluation, and key technological breakthroughs, achieving seamless connection between educational resources and industrial needs in space and logic.

The talent cultivation model driven by collaborative research and development not only enhances the scientific research strength of regional industries, but also becomes a practical training ground for North University of China to cultivate high-level innovative talents. The school has broken down the barriers of traditional research groups and formed a mixed interdisciplinary project team consisting of teachers, enterprise engineers, graduate students, and senior undergraduate students to carry out joint research and development around the urgent needs of regional industries such as wide-bandgap semiconductor materials, characteristic power devices, MEMS sensors, and RF chips ^[10]. Driven by real scientific research projects, undergraduate students are no longer bystanders, but directly and deeply participate in the complete engineering loop from technical research, simulation scheme demonstration to experimental film production, testing analysis, and process optimization. This “immersive” training based on real industry challenges not only hones students’ systematic thinking and resilience in solving complex engineering problems, but also builds a strong talent pool by accurately delivering high-quality “specialized, refined, unique, and new” talents to provincial enterprises every year. This education model, which takes major industrial issues as the carrier and innovation ability cultivation as the core, provides a replicable and promotable practical model for the high-quality development of the national and regional integrated circuit field.

6. Conclusion

In summary, against the backdrop of New Engineering Education reform, the cultivation of innovative talents in integrated circuits is confronted with a fundamental tension between conventional pedagogical approaches and the rapidly evolving, highly engineering-oriented demands of the industry. Key challenges include slow updates to knowledge content, insufficient integration of industry and education, inadequate practical training, and overly rigid evaluation mechanisms. To address these issues, systematic reform of educational and teaching practices is essential. Taking North University of China as a case study, this paper has explored a comprehensive reform framework for IC talent cultivation through the following interconnected measures: (1) establishing a “One Quality, Three Abilities” educational system that tightly integrates value guidance with competency development; (2) leading the formation of a provincial-level industrial technology innovation alliance to foster an industry-academia-research ecosystem along the entire value chain; (3) co-building high-level practical training bases with enterprises to enhance students’ hands-on abilities in authentic engineering settings; and (4) conducting problem-driven joint R&D projects that translate scientific research resources into teaching content. Together, these initiatives constitute a holistic reform model that covers the full spectrum of talent cultivation, offering a viable pathway to bridge the gap between

talent supply and industrial demand. Furthermore, this reform experience can serve as a systematic reference for other institutions embarking on New Engineering construction and disciplinary transformation, thereby contributing to the broader advancement of engineering education innovation.

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