

Exploration and Practice of the Training Model for Field Engineers in Integrated Circuits from the Perspective of Municipal Industry-Education Consortia

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Abstract: This paper focuses on the core pain point of the mismatch between the training of field engineers in integrated circuits and regional industry needs based on the policy guidance of municipal industry-education consortia and the urgent need for field engineers in the integrated circuit industry. Using municipal industry-education consortia as the core carrier, it explores and constructs an innovative training model of "one core leading, four dimensions supporting, and five parties collaborating." The study employs literature review, field research, action research, and comparative experiments. Through current situation surveys, it clarifies the training pain points, constructs a training system adapted to the municipal industry chain, and conducts a two-year practical verification. The results show that this model can effectively improve students' professional abilities, optimize the construction of a dual-teacher team, deepen the efficiency of industry-education collaboration, and solve the problem of mismatch between talent training and industry needs. This study highlights the core ideas of industry-education integration and regional industry adaptation, possesses both practical feasibility and academic reference value, conforms to the academic norms of CPCI conference papers, and provides a replicable paradigm for the training of field engineers in similar majors.

Keywords: Municipal Industry-Education Consortium; Integrated Circuit Technology Major; Field Engineer; Industry-Education Integration; Talent Training Model

1. Introduction

Based on the national strategy of independent control of the integrated circuit industry and the policy requirements of the Ministry of Education's Special Training Program for Field Engineers, this paper clarifies the positioning of municipal industry-education consortia as the core carrier of regional industry-education integration, elucidates the real pain point of the mismatch between supply and demand for field engineers in the integrated circuit major, and anchors the core scenario and research premise of this study [1]. Currently, the integrated circuit industry has become a core pillar supporting the development of the digital economy. The shortage of field engineers in China is expanding year by year, but the existing training model is out of sync with industry job requirements [2]. Municipal industry-education consortia provide an important platform for solving this dilemma. This paper reviews the core experiences of internationally advanced engineering and technical talent training models such as the German dual system, American community colleges, and the Singapore Institute of Technology [3]. Their school-enterprise collaborative education and job competency-oriented training concepts provide important references for the training of field engineers in China's integrated circuit major [4]. This paper reviews relevant research results on the construction of municipal industry-education consortia, talent training in the integrated circuit major, and the special training of field engineers in China, clarifying that existing research often focuses on a single dimension and lacks systematic and coupled research [5]. This paper points out that existing research rarely uses municipal-level industry-education consortia as a core vehicle for deep and systematic research on the training of field engineers in integrated circuits, and lacks empirical training programs adapted to the characteristics of the regional industry chain [6]. Therefore, this paper clarifies the research boundaries and innovative entry points. Taking municipal-level industry-education consortia as the perspective, this paper focuses on three core modules: current status

survey, model construction, and practical verification of field engineer training in integrated circuits, clarifying the research boundaries and core tasks of each module [7]. The paper explains the research methods used, including literature review, on-site surveys of municipal industries and universities, action research, comparative experiments, and interviews. Literature review summarizes policies and research results; on-site surveys grasp the current status of municipal industries and training; action research promotes model implementation; comparative experiments verify effectiveness; and interviews supplement qualitative data [8]. The application scenarios and implementation paths of each method are clearly defined to ensure the scientific rigor and feasibility of the research.

2. Analysis of the Current Status and Problems of Integrated Circuit Technology Professional Talent Training

2.1 Survey on the Current Status of Training

2.1.1 Survey Design and Implementation

The core scope of this survey was clearly defined as upstream and downstream enterprises in the integrated circuit industry chain within the target city, vocational colleges and universities offering integrated circuit technology majors, semiconductor industry associations, and related research institutes [9]. The implementation process and sample coverage of the survey questionnaire, in-depth interviews, and job competency breakdown were clarified to ensure the authenticity and representativeness of the survey data. The survey adopted a combination of online questionnaires, offline interviews, and field visits, targeting 23 integrated circuit enterprises, 8 colleges and universities offering related majors, 1 semiconductor industry association, and 2 research institutes within the city. 56 enterprise questionnaires, 32 college questionnaires, and 218 student questionnaires were distributed, with 52, 30, and 209 valid questionnaires returned respectively, all with an effective return rate exceeding 90%. In-depth interviews were conducted with representatives from 12 key enterprises, 4 core colleges and universities, industry associations, and research institutes, breaking down the competency requirements of 18 core positions to form a complete survey dataset, providing solid data support for subsequent analysis.

2.1.2 Current Status of Job Demand in the Municipal Integrated Circuit Industry

The target city's integrated circuit industry segment layout is clearly defined, focusing on packaging and testing, and equipment maintenance, while also considering design support and testing verification [10]. Core positions include integrated circuit packaging and testing engineers, equipment maintenance engineers, and testing verification engineers. The core competency requirements for field engineers at each stage are broken down. Professional technical skills cover chip packaging processes, equipment debugging, and troubleshooting; field engineering skills emphasize complex problem-solving, process optimization, and quality control; and professional ethics emphasize a sense of responsibility and teamwork. A clear career path is established, progressing from junior field engineer to intermediate engineer and technical supervisor. It is determined that the city needs to add over 800 field engineers annually, with intermediate and senior-level talent accounting for 45% of the demand. The competency standards are characterized by "high-level expertise and strong practical skills."

2.1.3 Current Status of Integrated Circuit Professional Talent Training Supply in the City

The current situation of integrated circuit majors in relevant colleges and universities within the city, including training objectives, curriculum systems, practical training resource allocation, dual-teacher team building, and graduate employment quality, is analyzed to clarify the matching between talent training supply and industry demand. Currently, the eight colleges and universities in the city train an average of over 600 graduates annually [11]. The training objectives primarily focus on general technical skills, without being tailored to the specific characteristics of the regional industries. Theoretical courses account for 60% of the curriculum, while practical courses are insufficient. Only three colleges and universities have basic training centers, lacking advanced training equipment. Only 38% of teachers are dual-qualified (possessing both academic and industry experience), and most teachers lack practical experience in industry. The graduate employment rate related to their majors is 68%, but only 32% can quickly adapt to field engineer positions, indicating a significant mismatch between supply and demand.

2.2 Existing Core Problems

2.2.1 Misalignment between Training Objectives and Job Requirements in the City's Industrial Chain

The current training objectives are not tailored to the specific characteristics and job requirements of the city's integrated circuit industry. There is an overemphasis on theory and a neglect of practical skills, as well as general abilities and a lack of field engineering capabilities, resulting in a significant gap between the training objectives and the professional competency standards for field engineers. Most colleges and universities emphasize the transmission of basic theoretical knowledge, failing to optimize their objectives for the city's industry-specific focus on packaging and testing, and equipment maintenance. They neglect the cultivation of core competencies such as solving complex field problems and optimizing processes, making it difficult for graduates to quickly adapt to job requirements.

2.2.2 The industry-education collaboration mechanism is loose, and the collaborative effectiveness of city-wide entities is insufficient

Industry-university cooperation often remains at a superficial level, limited to affiliation and internship placements. It has not formed a closed-loop educational system involving multiple stakeholders across the city, including government, industry, enterprises, universities, and research institutions. Enterprises lack intrinsic motivation to participate in education, and the collaborative role of industry associations and research institutes has not been fully utilized. Enterprises focus primarily on short-term employment needs and are unwilling to invest resources in curriculum development and teaching implementation. Industry associations have not played their bridging role in setting job standards and evaluating talent. The technological resources of research institutes have not been effectively transformed into teaching resources, and a collaborative educational force has not been formed.

2.2.3 The curriculum system is out of sync with industry technology iterations, and on-site skills training is lacking

The teaching content lags behind the pace of technological iteration in the integrated circuit industry, failing to incorporate the latest process standards, production projects, and technical specifications of leading municipal enterprises. The integration of on-the-job training, courses, competitions, certifications, and innovation is merely a formality, lacking project-based and scenario-based curriculum resources specifically for cultivating on-site engineers' capabilities. Course content largely relies on traditional textbooks, failing to include the latest packaging and testing processes and core technologies for equipment operation and maintenance. The integration of on-the-job training, courses, competitions, certifications, and innovation remains superficial, failing to deeply integrate vocational skills certificates and skills competition content with the curriculum system, and lacking real-world project implementation.

2.2.4 The support system for practical training resources and dual-teacher teams is weak

High-end practical training equipment for integrated circuit majors requires significant investment and is rapidly iterated. A single school cannot afford to build a complete supply chain of practical training resources, resulting in a disconnect between on-campus training scenarios and real-world production sites in enterprises. On-campus teachers lack front-line engineering practice experience in integrated circuit enterprises, and there is a lack of incentive mechanisms for enterprise technical backbones to participate in teaching. The construction of a dual-teacher team cannot meet the requirements for cultivating highly skilled professionals. 2.2.5 The talent evaluation system is too simplistic and fails to simulate real-world production scenarios in enterprises. Most university teachers are recent graduates with limited practical experience in industry. There are no clear incentives for enterprise technical personnel to participate in teaching, resulting in low engagement.

2.2.5 The current evaluation model relies primarily on written exams and skills assessments within universities

It fails to establish a process-oriented evaluation system covering the entire training cycle and focusing on solving complex engineering problems on-site, thus failing to scientifically assess the core professional competencies of on-site engineers. Evaluation content emphasizes theoretical knowledge and basic skills, neglecting core competencies such as on-site problem-solving and process optimization.

The evaluation is conducted solely by university teachers, with enterprises not participating in core evaluation stages, leading to a disconnect between evaluation results and job requirements.

The current evaluation model relies mainly on written exams and skills assessments within universities, lacking participation from enterprises in core evaluation stages.

3. Construction of Field Engineer Training Model

3.1 Construction Principles and Guiding Ideology

Guided by relevant national vocational education industry-education integration policies, with the municipal industry-education consortium as the core carrier, and with the cultivation of core competencies of field engineers in integrated circuits as the fundamental goal, this model aims to meet the job requirements of the municipal integrated circuit industry chain, construct a talent training model with multi-party collaboration among government, industry, enterprises, schools, and research institutions, and a closed-loop system covering the entire chain, serving the high-quality development of the regional integrated circuit industry and the independent cultivation of talent. The training model adheres to the following principles: Demand-oriented approach: Centered on the needs of field engineers in the city's integrated circuit industry, the entire training process is customized to ensure a precise match between training content and job requirements. City-wide collaboration approach: Relying on the city's industry-education consortium, it integrates resources from government, industry, enterprises, schools, and research institutions within the region, breaking down barriers and forming a collaborative force for talent cultivation. Competency-based approach: Centered on cultivating the core professional competencies of field engineers, the training system and teaching model are restructured, emphasizing practical skills and on-site problem-solving abilities. Work-study integration approach: A dual-subject training system involving schools and enterprises is implemented, achieving deep integration of learning scenarios and production sites, ensuring on-site learning, on-site practice, and on-site implementation. Multi-dimensional evaluation approach: A process-oriented evaluation system with multi-subject participation and coverage of the entire training cycle is established to ensure that training quality accurately aligns with job requirements.

3.2 Core Framework of the Training Model

3.2.1 Overall Model Architecture

The model innovatively constructs a "one-core leadership, four-dimensional support, and five-party collaboration" training model for field engineers in integrated circuits, driven by the city's industry-education consortium. It clarifies the core logic of the model, the internal connections and operational paths of each module, forming a complete closed-loop training system. The framework diagram is as follows shown in Figure 1:

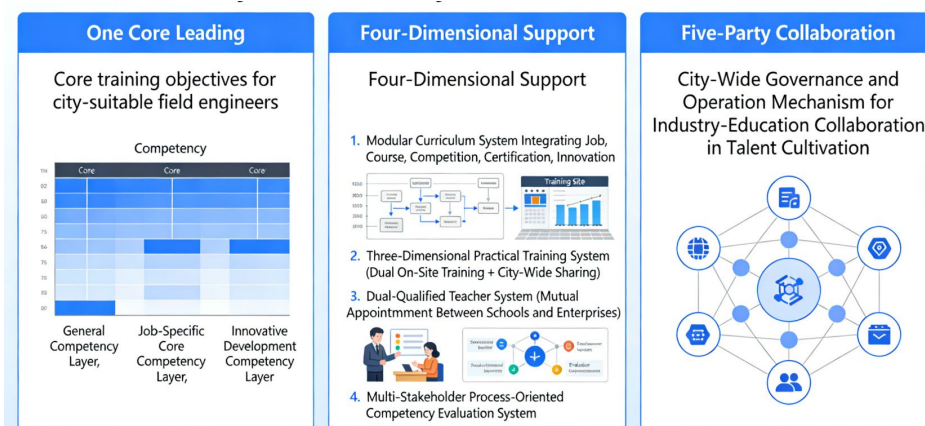


Fig.1 Framework Diagram

3.2.2 Core Leadership: Anchoring the Core Training Objectives of Field Engineers Adapted to the City

Based on the survey results of the integrated circuit job cluster in the city, a core competency matrix for field engineers is constructed, setting a three-tiered training objective: a general competency layer, a job-specific core competency layer, and an innovation and development competency layer. This aligns with the entire career growth cycle of field engineers, achieving a precise match between training objectives and the needs of the city's industries. The general competency layer covers ideological and political literacy, communication and collaboration, and lifelong learning ability, adapting to all field engineer positions; the job-specific core competency layer combines sub-tracks such as packaging and testing, and equipment maintenance in the city, specifically cultivating core skills such as chip packaging technology, equipment debugging, fault diagnosis, and quality control; the innovation and development competency layer focuses on cultivating innovative abilities such as process optimization and technological improvement, adapting to the career development needs of mid-to-senior level field engineers, forming a training objective system of "basic standards met, core focus emphasized, and innovation empowered."

3.2.3 Four-Dimensional Support: Constructing Four Core Training Systems

(1) Modular Curriculum System Integrating Jobs, Courses, Competitions, Certifications, and Innovation

Centered on job competency, based on national on-site engineer professional standards, and using real production projects from leading municipal enterprises as a vehicle, the curriculum has been restructured into four major modules: a public foundation module, a professional core module, a job-oriented module, and an innovation and expansion module. In collaboration with municipal enterprises, loose-leaf textbooks and project-based teaching resources have been developed to ensure that curriculum content is updated in sync with industry standards and cutting-edge technologies. The public foundation module covers ideological and political education, mathematics, and professional ethics; the professional core module includes core courses such as integrated circuit principles, packaging and testing technology, and equipment operation and maintenance fundamentals; the job-oriented module features specialized courses in areas such as packaging and testing and equipment operation and maintenance; and the innovation and expansion module integrates skills competitions, enterprise technological transformation projects, and innovation and entrepreneurship practices, with 12 sets of loose-leaf textbooks and 8 project-based teaching cases developed to achieve deep integration of job skills, courses, competitions, certifications, and innovation.

(2) A Three-Dimensional Training System Combining Dual On-Site Training and City-wide Sharing

Leveraging the resources of the municipal industry-education consortium, a dual-scenario approach is created, combining simulated training sites on campus with real production sites in enterprises. This involves coordinating resources from public training bases, research institute laboratories, and high-end production workshops of leading enterprises within the city, establishing a city-wide resource-sharing mechanism to address the pain point of insufficient investment in training by individual schools. A teaching model of alternating work and study and on-the-job rotation is promoted to achieve "learning on-site, practicing on-site, and doing on-site." The simulated training sites on campus are equipped with virtual simulation platforms and basic training equipment to complete basic skills training. Three on-site engineer academies and five internship bases are jointly established in real production sites in enterprises, allowing students to participate in real production projects in stages. The city-wide shared training resources integrate two public training bases and three high-end workshops in enterprises, achieving the sharing of high-end equipment, with no less than 800 hours of open training time annually.

(3) A Dual-Teacher Faculty System of Mutual Employment and Empowerment between Schools and Enterprises

Integrate professional teachers from universities, technical backbones from enterprises, and experts from research institutes within the city to establish a unified city-wide integrated circuit professional teacher sharing database. Supporting incentive and guarantee mechanisms related to professional title evaluation, performance appraisal, and commendation will enhance the teaching ability and enthusiasm of the dual-qualified teacher team. The teacher sharing database includes over 50 members, with enterprise technical backbones accounting for 60%. University teachers will spend no less than 3 months annually on on-the-job training in enterprises to participate in enterprise technical research. Enterprise mentors will participate in no less than 40 hours of teaching ability training annually and will be included

in the university's part-time teacher management system, receiving preferential treatment in professional title evaluation and commendation. The goal is to increase the proportion of dual-qualified teachers to over 80%.

(4) A Process-Oriented Competency Evaluation System with Multi-Party Participation

A joint evaluation mechanism involving government, industry, enterprises, universities, and research institutions has been established. This mechanism emphasizes the core voice of enterprises in assessing on-site engineering capabilities, breaks away from the single examination-based assessment model, and focuses on evaluating students' project completion quality, on-site problem-solving abilities, process optimization results, and professional qualities. It combines formative and summative assessments to achieve dynamic management of talent training quality throughout its entire lifecycle. Formative assessments account for 60%, covering classroom performance, practical training results, and enterprise practice performance; summative assessments account for 40%, with questions jointly set by universities and enterprises, focusing on on-site practical skills and project problem-solving abilities. The five evaluation entities participate in the scoring in a 2:1:3:3:1 ratio to ensure the scientific and fair evaluation results.

3.2.4 Five-Party Collaboration: Establishing a City-wide Industry-Education Collaborative Education Governance and Operation Mechanism

An Integrated Circuit Major Construction Guidance Committee will be established, composed of the government, semiconductor industry associations, leading integrated circuit enterprises in the city, universities offering the program, and microelectronics research institutes. The committee will clarify the responsibilities and rights of each party, establish a regular joint meeting system, a dynamic early warning mechanism for talent demand, a resource-sharing mechanism, and a win-win mechanism between universities and enterprises. This will address the core pain point of insufficient motivation for collaborative education and provide governance guarantees for the implementation of the model. The government will be responsible for policy guidance and financial support; industry associations will be responsible for setting job standards and talent evaluation; enterprises will be responsible for providing training scenarios and practical projects; universities will be responsible for teaching implementation and talent cultivation; and research institutes will be responsible for technical support and resource transformation. A joint meeting will be held monthly, and a talent demand early warning will be issued quarterly. A resource-sharing platform will be established, and enterprises participating in education can enjoy tax incentives and subsidies, forming a long-term collaborative mechanism.

4. Practical Application and Effectiveness Verification

4.1 Practical Application Process

4.1.1 Practical Basis and Target Groups

The practical training was based on the City A Integrated Circuit Industry-Education Consortium, led by the Education Bureau and the Industry and Information Technology Bureau, and comprised of three leading integrated circuit companies, eight colleges offering related majors, one semiconductor industry association, and two research institutes, possessing a well-established foundation for collaborative education. The experimental group consisted of 120 students from the 2022 cohort of an integrated circuit technology major at a vocational college, trained using the model described in this paper. The control group consisted of 118 students from the 2021 cohort of the same major, trained using a traditional model, and conducted a two-year teaching practice in collaboration with three leading integrated circuit companies and one microelectronics research institute within the city. The practice period was from September 2022 to June 2024, with key implementation boundaries including curriculum revision, course restructuring, practical training implementation, and evaluation.

4.1.2 Implementation Steps

First, relying on the Consortium's Professional Development Steering Committee and combining it with the city's industrial needs, revise the talent training program and accurately define the training objectives, clarifying the three-tiered training goals and core competency requirements.

Second, the university and enterprises jointly restructure the curriculum system, developing 18 courses in 4 modules, compiling 12 sets of loose-leaf textbooks and 8 project-based teaching cases, incorporating the latest enterprise process standards.

Third, jointly build 3 on-campus simulation training centers, 5 enterprise internship bases, and 2 field engineer academies, completing the formation and training of a dual-qualified teaching staff, and including 52 teachers in the shared teaching resource pool.

Fourth, promote the reform of the teaching model of dual mentors from both the university and enterprises, and alternating work and study, with students spending no less than 8 weeks each semester in enterprise practice, implementing project-based teaching, and participating in real production projects throughout the process.

Fifth, implement the five-party joint process-based evaluation system, clarifying evaluation indicators and scoring standards, tracking and recording student training throughout the process, and optimizing the teaching program in a timely manner.

4.1.3 Practice Process Control

A clear quality control mechanism was established for the practice process, including a monthly joint meeting system between the university and enterprises. This system regularly tracks the implementation of teaching, student practice, and enterprise feedback, allowing for timely optimization and adjustment of the practice plan to ensure the standardization of the practice process and the authenticity of the data. A quality control team was established, jointly led by the university and enterprises, to conduct monthly teaching inspections and quarterly practice evaluations. Student practice files and teacher teaching files were established to record the entire practice process and teaching situation. Feedback channels were opened to collect opinions and suggestions from enterprises, students, and teachers. The teaching plan was optimized 6 times, and the practical training arrangements were adjusted 4 times, ensuring the orderly progress of the practice work.

4.2 Verification of Practice Effectiveness

4.2.1 Verification Methods and Dimensions

Using comparative experiments, statistical analysis, and interview surveys, this study compared relevant data between the experimental and control groups across four core dimensions: student training quality, faculty development, depth of industry-education collaboration, and industry service value, to verify the effectiveness of the training model. The comparative experiment focused on the differences in core indicators between the two groups; the statistical analysis quantified the effectiveness data; and the interview surveys collected qualitative feedback from municipal industry associations, partner companies, students, and instructors to ensure the verification results were comprehensive, objective, and credible.

4.2.2 Quantitative Effectiveness Verification

Regarding student training quality, comparing the core data between the experimental and control groups, the experimental group showed significantly better performance in all indicators. Specific data are shown in Table 1 below. Table 1 shows that the experimental group's professional qualification certificate acquisition rate increased by 34.7%, skills competition award rate increased by 28.9%, professionally relevant employment rate increased by 23.7%, average starting salary after graduation increased by 18.5%, and company retention rate increased by 29.8%. This fully demonstrates that the training model effectively improves students' professional abilities and employment quality, meeting the needs of on-site engineer positions.

Table 1 Quantitative Effectiveness

| Evaluation indicators | Experimental group (n=120) | Control group (n=118) | Increase |
|---|-------------------------------|--------------------------|----------|
| Professional qualification certificate acquisition rate | 89.20% | 54.50% | 34.70% |
| Skills competition award rate | 37.50% | 8.60% | 28.90% |
| Employment rate related to major | 91.70% | 68.00% | 23.70% |
| Company retention rate | 76.70% | 46.90% | 29.80% |

In terms of faculty development and the depth of industry-education collaboration, all indicators showed significant improvement during the practice period, as detailed in Table 2. Table 2 shows that the proportion of dual-qualified teachers increased by 40.5% compared to before the practice; 18 school-enterprise cooperative courses/textbooks were developed; and 1.2 million yuan was received from horizontal research projects. Enterprise participation in teaching totaled 2800 class hours; the number of high-quality internship positions increased by 62.5% compared to before the practice; and 8 million yuan was invested in jointly built school-enterprise training bases. This fully demonstrates that this model effectively optimizes the faculty structure and deepens the efficiency of industry-education collaboration.

Table 2 Indicator Results

| Evaluation Dimensions | Evaluation indicators | Before practice | After practice | Increase |
|--|---|-----------------|----------------|----------|
| Teacher team building | The proportion of dual-qualified teachers | 38.00% | 78.50% | 40.50% |
| Teacher team building | Number of school-enterprise cooperative courses/textbooks developed | 0 items | 18 items | — |
| Deepening Industry-Education Collaboration | Total time spent by enterprises in teaching | 0 class | 2800 class | — |
| Deepening Industry-Education Collaboration | Number of high-quality internship positions available | 40 individual | 65 individual | 62.50% |

In terms of industry service value, during the practice period, the experimental group students participated in 8 enterprise technology transformation projects, solved 15 front-line technical problems for enterprises, and provided 85 on-site engineers who met the job requirements, effectively alleviating the talent shortage of integrated circuit enterprises in the city and creating direct economic benefits of more than 3 million yuan for enterprises, fully demonstrating the practical application value of the research.

4.2.3 Qualitative Effectiveness Feedback

The feedback and evaluation of this training model practice from municipal industry associations, partner enterprises, students, and instructors were summarized to clarify the actual effects of the model in adapting to industry needs, improving students' professional abilities, and deepening industry-education integration. At the same time, the problems discovered during the practice were summarized. Industry associations reported that the students trained by this model were highly adaptable and effectively filled the talent gap for on-site engineers in the city; partner enterprises reported that students' on-site operation and problem-solving abilities were significantly improved, enabling them to quickly integrate into their positions and reduce enterprise training costs; students reported that project-based teaching and enterprise practice improved their practical skills and significantly enhanced their employment competitiveness; instructors reported that dual-teacher collaborative teaching and resource sharing improved teaching quality and also enhanced their own engineering practice abilities. Meanwhile, practice also revealed issues such as insufficient timeliness in aligning some course content with the latest technological iterations and the need for further improvement in the teaching capabilities of enterprise mentors, providing direction for subsequent model optimization.

5. Conclusion

This paper, based on the city-level industry-education consortium construction policy and the urgent talent needs of the integrated circuit industry, focuses on the pain points in field engineer training and constructs an innovative training model of "one core leading, four-dimensional support, and five-party collaboration." Through two years of practical verification, it is clear that this model can effectively solve problems such as the mismatch between talent training and industry needs, and loose industry-education collaboration, significantly improving students' professional abilities, optimizing the construction of the dual-teacher team, and deepening the efficiency of industry-education collaboration, thus providing high-quality field engineers for the city's integrated circuit industry. It possesses strong practical effectiveness and application value. The core innovation of this study is the deep coupling of the city-level industry-education consortium with the training of field engineers in integrated circuit majors, constructing a closed-loop training system adapted to the regional industry characteristics. However, this

study has limitations such as a narrow practical scope, limited sample coverage, and the need for further optimization of model adaptability. In the future, we will expand the scope of practical application, optimize the details of the model by aligning with the forefront of integrated circuit industry technologies, and improve the long-term mechanism for diversified and collaborative talent cultivation, providing a replicable and scalable reference paradigm for the training of field engineers in similar professions nationwide.

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