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Digital Twin-Driven Industry-Education Integration Model: A Case Study of IC Packaging & Testing Training Course Development

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Abstract

The rapid digital transformation of the integrated circuit (IC) industry has intensified the structural mismatch between talent supply and demand. Digital twin (DT) technology, which enables bidirectional mapping between physical and digital spaces, offers a promising solution to three persistent problems in vocational training: difficult technology implementation, lack of teaching resources, and fragmented competency development. Based on the collaboration between Wuhan Vocational and Technical University and Boxin Semiconductor Technology Co., Ltd., this paper constructs a progressive "Technology–Scenario–Competency" cultivation system. Key components include a hierarchical competency development system, job competency map-based curriculum design, and modular training combining virtual and physical elements, supported by a dynamic resource updating mechanism. Results show that the DT-driven model shortens students' job adaptation period significantly and enables rapid translation of industrial technologies into teaching content, providing a replicable paradigm for vocational education digital transformation.

Keywords: *Digital twin; industry-education integration; integrated circuit; training teaching; vocational education*

1. Introduction

The global IC industry, especially the packaging and testing (PAT) segment, faces a talent shortage exceeding 70% in emerging areas such as intelligent testing and 3D packaging simulation (MIIT, 2023). Graduates often possess outdated skills and a disconnect between knowledge and industry needs. China's national implementation plan for industry-education integration explicitly calls for transforming real production scenarios into teaching resources.

Digital twin (DT) technology, by creating virtual replicas of physical systems, has been widely used in industry for equipment maintenance and process optimization. However, its pedagogical potential remains underexplored. This paper, based on the cooperation between Wuhan Vocational and Technical University and Boxin Semiconductor, explores a DT-driven industry-education integration model to address key training challenges.

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2. Alignment Logic of DT Technology and Industry-Education Integration

2.1 How DT Empowers Training Teaching

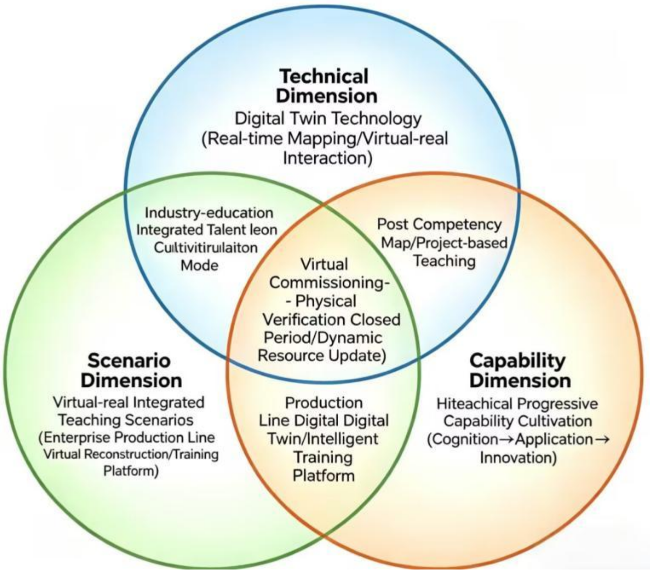
DT technology offers three main advantages for vocational training: (1) scenario reproducibility – virtualizing real production environments, avoiding high costs and risks; (2) process visualization – making internal mechanisms visible, aiding understanding; (3) verifiable decision-making – allowing students to test solutions in a virtual space before physical validation, forming a closed loop of "virtual debugging → physical verification → optimization iteration."

2.2 Demand from Industry-Education Integration

Traditional integration faces three barriers: difficulty bringing real production lines to campus, slow translation of new technologies into teaching materials, and misalignment between student competencies and job requirements. DT technology overcomes these by (1) virtualizing real PAT lines on campus; (2) enabling seamless data connection via OPC UA middleware to enterprise MES systems; and (3) allowing parameterized task design for precise competency-job mapping.

3. Construction of the DT-Driven Industry-Education Integration Model

Based on the practical exploration, a "Technology–Scenario–Competency" three-dimensional integration model is proposed (Fig. 1).



3.1 Hierarchical Progressive Competency Development

A three-level "Cognition–Application–Innovation" framework is adopted:

Cognition: Operate DT tools, perform equipment monitoring.

Application: Use real enterprise work orders (e.g., yield improvement) to model production lines and optimize parameters.

Innovation: Participate in enterprise R&D projects (e.g., AI defect classification) and propose implementable solutions.

Students complete at least three real enterprise projects before graduation under a dual-tutor system (enterprise engineer + university teacher).

3.2 Job Competency Map-Based Curriculum Development*

A competency map is built for PAT jobs (e.g., process optimization, equipment maintenance). For example:

Cognition → "Fundamentals of DT Modeling"

Application → "Virtual Debugging of IC Packaging"

Innovation → "Deep Learning for Defect Detection"

A dynamic curriculum generation system automatically recommends course modules based on input work orders (e.g., "equipment modeling + AI inspection" → matching the above two courses).

3.3 Modular Training Courses Integrating Virtual and Physical Elements

A three-tier modular system is designed:

Basic modules: "Fundamentals of DT Modeling", "Industrial Data Acquisition"

Specialized modules: "Virtual Debugging of IC Packaging", "DT System O&M for PAT Lines"

Advanced modules: "AI-Driven DT Optimization", "Edge Computing and Real-Time Control"

Resources built include:

Equipment model library: 50+ industrial equipment DTs at L4 interactive level.

Process database: 2,000+ multi-physics parameter sets simulating temperature, pressure, etc.

Real case library: 100+ real enterprise work orders with fault tree analysis tools.

An intelligent training platform based on OPC UA connects to 90% of mainstream MES systems, enabling a closed loop of "virtual debugging – physical verification – optimization iteration" and generating competency radar charts in real time.

4. Collaboration Mechanisms and Practical Outcomes

4.1 Dynamic Resource Updating Mechanism

A fast track transforms new industrial technologies (e.g., Chiplet simulation, AI inspection) into teaching resources, shortening the update cycle from 1–2 years to less than 6 months. A shared resource platform, piloted in 6 vocational colleges, serves over 1,000 students annually, using a credit exchange system to incentivize contributions.

4.2 Outcomes After One Year (Wuhan Vocational and Technical University)

Student competencies: >90% of 100 pilot students independently completed PAT line modeling and optimization tasks; 30% contributed to enterprise projects recognized by the company. Job adaptation period reduced from 6–12 months to <3 months.

Teaching resources: Full-coverage PAT digital twin resource library updated quarterly.

School-enterprise cooperation: Joint R&D center established; enterprises place pre-research projects on campus.

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5. Conclusion and Outlook

This study demonstrates that a digital twin-driven industry-education integration model effectively solves the core problems of difficult technology implementation, lack of teaching resources, and fragmented competency development in vocational training. The hierarchical competency system, job map-based curriculum design, and virtual-physical modular training, together with a dynamic resource updating mechanism, significantly improve talent cultivation quality and adaptability.

Future research should explore: (1) applicability in other disciplines; (2) deep integration of AI with DT for intelligent learning diagnosis; and (3) a quantitative evaluation system for integration effectiveness.

References

1. Ministry of Industry and Information Technology. (2023). 2023 Integrated Circuit Industry Talent Development Report.

2. Xu, L., Jiang, X., Li, H., Wang, K., & Ma, Y. (2025). Construction and Practice of a Virtual Simulation Training and Teaching Environment for IC Technology Majors in Higher Vocational Colleges. Home Appliance Maintenance, (12).

3. Dong, F. (2025). Exploration of a New Teaching Model in Higher Vocational Colleges Based on Virtual Simulation Training Bases: Taking the Construction of IC Professional Groups as an Example. Office Automation, (9).

4. Zhao, X., Jia, C., Ai, Y., & Luo, F. (2025). Research on a Practice Teaching Model for IC Manufacturing Processes Combining Virtual and Real Elements. In Proceedings of the Ideological and Political Education Sub-forum of the 2025 Higher Education Development Forum (Volume 1).

5. Ministry of Education. (2023). Implementation Plan for Empowering and Enhancing Industry-Education Integration in Vocational Education (2023-2025).

6. Zhu, J., Fan, G., Wang, Y., & Li, T. (2024). Design of a Virtual Simulation Experiment Teaching Platform for Integrated Circuits. Application of Integrated Circuits, (7).

7. Li, H. (2024). Application of Virtual Simulation Training Technology in Integrated and Compound Teaching of Integrated Circuits. Application of Integrated Circuits, (3).

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