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Generative AI-Empowered Reform of Key Elements in ICT Talent Cultivation

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ABSTRACT

The rapid advancement of Generative Artificial Intelligence (GenAI) and intelligent agent technologies is continuously reshaping job structures, work patterns, and competency requirements within the Information and Communication Technology (ICT) industry, thereby creating new demands for vocational ICT talent cultivation. Addressing challenges such as the mismatch between program structures and industrial needs, insufficient transformation of authentic engineering projects into instructional tasks, delayed updating of teaching materials and resources, inadequate digital-intelligence competencies among teachers, and the disconnect between training environments and real workplace scenarios, this study follows the reform requirements for the five key elements of vocational education: programs, curricula, teaching materials, teachers, and practical training. A "5×3" vocational education agent matrix is proposed, taking the five key teaching elements as the vertical dimension and industry–education integration, teaching reform, and research and industry engagement as the horizontal dimension, thereby establishing a collaborative reform framework. Based on this framework, reform pathways are developed for dynamic mapping of industrial demands, transformation of enterprise engineering tasks, dynamic construction of teaching resources, teacher competency development, and engineering-oriented training environment construction. Furthermore, a collaborative teaching model involving teachers, intelligent agents, and students is established. Real-world smart shipping projects are employed to support project-based learning, while multi-source learning evidence is integrated to diagnose and support student development. This study provides a practical framework for systematically empowering the reform of key teaching elements in vocational ICT education through Generative AI and offers an industry-oriented implementation pathway for cultivating interdisciplinary talents in the "Information Technology + Shipping" domain.

KEYWORDS

Generative Artificial Intelligence (GenAI); ICT talent cultivation; Key teaching elements; Intelligent agent matrix; Project-based learning.

1. INTRODUCTION

According to the Opinions on Deepening the Reform of Key Teaching Elements in Vocational Education issued by the Ministry of Education, vocational education should carry out systematic reforms centered on the five key teaching elements-programs, curricula, teaching materials, teachers, and practical training-to ensure that talent cultivation aligns with emerging industrial technologies and evolving job competency requirements [1]. Against this backdrop, the rapid development of large language models (LLMs), Generative AI (GenAI), and intelligent agents has profoundly influenced ICT talent cultivation in higher vocational education. In addition to foundational competencies such as software development and system deployment, modern ICT occupations increasingly demand

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interdisciplinary integration, human–AI collaboration, and engineering-oriented problem-solving capabilities, thereby accelerating the transformation of vocational ICT education [2].

At the same time, the application paradigm of artificial intelligence in education is undergoing a significant shift. Research attention has moved beyond the use of general-purpose Generative AI for content generation toward the deployment of intelligent agents and multi-agent systems in complex educational and professional scenarios [3]. Although extensive explorations have been conducted in both academia and industry, systematic studies that specifically address the reform of the five key teaching elements in vocational ICT education remain limited.

Research on the underlying technologies of intelligent agents began relatively early in international academia and industry. Organizations such as OpenAI and research teams at Stanford University have focused on key technologies including retrieval-augmented generation (RAG), memory mechanisms, tool invocation, autonomous planning, and reasoning capabilities, seeking to enhance agents' capacity for complex task execution [4]. Within educational settings, most international studies have concentrated on intelligent tutoring systems that support personalized learning. Representative examples include Khan Academy's AI-assisted learning initiatives, which emphasize knowledge assistance, adaptive learning pathways, and individualized instruction in general and higher education contexts [5]. More recently, multi-agent collaboration has emerged as a major research direction, with scholars assigning specialized roles to different agents in order to simulate collaborative decision-making and instructional processes in educational environments.

China has closely followed global developments in intelligent technologies and has achieved notable progress in AI-assisted teaching and intelligent instructional design. As reforms of key teaching elements in vocational education continue to advance, researchers have begun to reflect on the limitations of isolated AI applications, fragmented data resources, and disconnected educational elements. Consequently, research perspectives have gradually shifted toward the systematic reconstruction of educational ecosystems through intelligent agent matrices. For example, Northwest Normal University and Tencent jointly developed the "Penguin Teacher Assistant," which explores AI-supported learning companionship and data-driven instructional evaluation. Zhejiang University established the "ZJU Sir" platform, an integrated intelligent-agent matrix serving research, teaching, and administrative functions [6].

A search of the China National Knowledge Infrastructure (CNKI) database using the keywords "intelligent agents" and "vocational education" yielded only eight related publications, indicating that this research field remains in its early stages. Bi and Zhang proposed a vocational education agent matrix that combines three vertical layers-decision-making, collaboration, and execution-with three horizontal domains-industry–education integration, institutional governance, and teaching reform-highlighting the role of intelligent agents in bridging the gap between education and industry [7]. Liu et al. explored the mechanisms and implementation pathways of AI-agent-enabled symbiotic training spaces for vocational education [8]. In addition, vocational institutions such as Wenzhou Polytechnic and Dalian Vocational and Technical College have carried out pilot applications of intelligent agents, demonstrating their practical feasibility. Focusing specifically on vocational ICT education, Ren and Zhang investigated the use of teaching agents in project-based computer education, examining their roles in project decomposition, classroom implementation, and instructional resource allocation [9].

Artificial intelligence is evolving from a supplementary instructional tool into a fundamental force reshaping educational ecosystems. Intelligent agents are rapidly transitioning from isolated autonomous systems toward collaborative multi-agent matrices, which are becoming a dominant paradigm for educational intelligence and digital transformation. Against this background, this study focuses on the characteristics of ICT talent cultivation in higher vocational education and proposes a specialized vocational education agent matrix that aligns with the five key teaching elements and covers the entire teaching process. The proposed framework seeks to address persistent challenges, including inadequate alignment with occupational requirements, disconnection between teaching

content and industrial practice, delayed updating of educational resources, insufficient digital competencies among teachers, and technological gaps in training environments. Through systematic integration of Generative AI and intelligent agents, the study aims to provide a practical pathway for promoting comprehensive reform of ICT talent cultivation in vocational education.

2. CHALLENGES IN ICT TALENT CULTIVATION REFORM

The extensive application of AI is profoundly reshaping ICT talent development in higher vocational education. The accelerating deployment of intelligent agents has created new industry expectations for highly skilled professionals, including rapid adaptability, interdisciplinary competencies, and effective human–AI collaboration in practical work. These challenges identify the priorities for reforming the key teaching elements of ICT talent development and underscore the urgency of such reform.

2.1 Accelerated ICT Technological Innovation and Lagging Alignment of Program Structures

The ICT industry is characterized by rapid technological iteration, frequent updates of technology stacks, and continuous restructuring of occupational boundaries. Generative AI and intelligent agents are increasingly being integrated into software development, data processing, intelligent applications, and system operation and maintenance, leading to substantial changes in job tasks and competency requirements. However, adjustments to vocational ICT programs, curriculum systems, and talent cultivation schemes often follow relatively long development cycles. As a result, instructional content frequently lags behind industrial technological advancement.

Many ICT programs continue to emphasize traditional competencies such as programming, database management, and network technologies, while providing insufficient coverage of emerging capabilities including intelligent programming, agent development, human–AI collaboration, and AI application deployment. Consequently, a temporal mismatch has emerged between educational provision and the rapidly evolving structure of ICT occupations. Improving the responsiveness and adaptability of vocational ICT programs has therefore become an urgent priority.

2.2 Insufficient Transformation of Authentic Engineering Projects into Project-Based Learning Tasks

ICT research and development activities are deeply embedded within specific business contexts. Software engineering, data engineering, intelligent applications, and system operations all require practitioners to consider business rules, data quality, technical architectures, interface coordination, and deployment constraints. Isolated skill training or fragmented knowledge instruction is therefore insufficient to prepare students for authentic workplace tasks.

At present, practical teaching in many vocational institutions still relies heavily on instructor-designed projects in which students follow predefined procedures to complete assigned tasks. Such projects often differ substantially from real enterprise workflows, technical standards, and delivery requirements. Particularly in the era of AI-assisted development, students can readily obtain code snippets or complete solutions through intelligent tools, yet frequently lack opportunities to develop engineering competencies such as requirements analysis, solution evaluation, testing and verification, and fault diagnosis.

As a result, authentic enterprise engineering projects are not effectively transformed into progressive instructional tasks that support systematic competency development. This gap ultimately limits students' ability to solve complex practical problems and reduces their readiness for professional ICT positions.

2.3 Rapid Evolution of ICT Standards and Technology Frameworks Leading to Insufficient Dynamic Updating of Teaching Materials

ICT technologies are characterized by diverse technical standards, development frameworks, and software tools, all of which evolve rapidly. Programming languages, database systems, middleware platforms, AI frameworks, and cloud-native technologies undergo continuous updates, while enterprise development specifications are frequently adjusted in response to technological change.

Traditional teaching materials are generally organized around relatively stable bodies of knowledge and often require lengthy cycles for compilation, publication, and revision. Consequently, they struggle to reflect the latest tools, frameworks, and engineering practices currently adopted by industry. Although some textbooks have incorporated AI-related content, many remain focused on tool introductions and operational procedures, with limited integration of authentic development processes, engineering standards, and real-world business scenarios.

This creates a fundamental tension between the relative stability of educational materials and the rapid evolution of ICT technologies. There is therefore an urgent need to establish a resource ecosystem that integrates stable foundational knowledge with dynamic industry cases and continuously updated learning resources.

2.4 Rapid Transformation of ICT Technology Stacks and Insufficient Improvement of Teachers' digital and AI-enabled teaching and Social Service Competencies

ICT teachers are required not only to master foundational technologies such as programming, databases, networks, and data engineering, but also to continuously keep pace with emerging technologies including Generative AI, intelligent agents, cloud computing, and big data. Compared with traditional disciplines, ICT education therefore places greater demands on both the breadth of teachers' technology stacks and their capacity for continuous technological updating.

At present, some vocational ICT teachers have limited experience in enterprise engineering practice. Their understanding of AI-assisted development, intelligent agent applications, and emerging development workflows is primarily acquired through short-term training, making it difficult to translate changes in industrial technologies into teaching tasks and classroom practice in a timely manner. At the same time, when participating in enterprise technical services, teachers face challenges associated with complex projects, rapid technological evolution, and high requirements for engineering experience. Consequently, teachers' digital and AI-enabled teaching competencies and their capabilities in providing technical services, professional training, and applied research for enterprises remain insufficiently developed, limiting their ability to fully fulfill their roles as dual-qualified teachers.

2.5 Rapid Upgrading of ICT Technology Stacks and the Disconnect between On-Campus Training Environments and Real Workplace Settings

Practical ICT positions rely heavily on development tools, runtime environments, data resources, and technology platforms. Enterprises typically organize their work through engineering-oriented practices such as continuous integration, version control, containerized deployment, automated testing, and AI-assisted development. In contrast, on-campus training environments are often constrained by software versions, hardware configurations, resource maintenance, and security management. Some practical training activities still focus primarily on standalone development, fixed cases, and procedure-oriented operations, resulting in a significant gap between campus-based training environments and authentic enterprise development settings.

As technology stacks evolve rapidly, the updating of on-campus training environments also tends to lag behind industrial practice. Consequently, students may have limited opportunities to experience

authentic data flows, development processes, testing standards, and fault-diagnosis procedures during their training. It is therefore necessary to transform practical training environments from being primarily "equipment-oriented" to being "engineering-oriented," thereby strengthening their alignment with the technological environments and work processes of real enterprise positions.

3. GENERATIVE AI-EMPOWERED REFORM OF KEY TEACHING ELEMENTS

3.1 Constructing an Intelligent Agent Matrix Integrating Key Teaching Elements and Application Scenarios

This study takes the five key teaching elements as the vertical dimension and industry–education integration, teaching reform, and research and industry engagement as the horizontal dimension, thereby constructing a "5×3" vocational education intelligent agent matrix, as shown in Figure 1. The vertical dimension addresses which educational elements should be reformed, while the horizontal dimension addresses through which application scenarios the reform can be implemented.

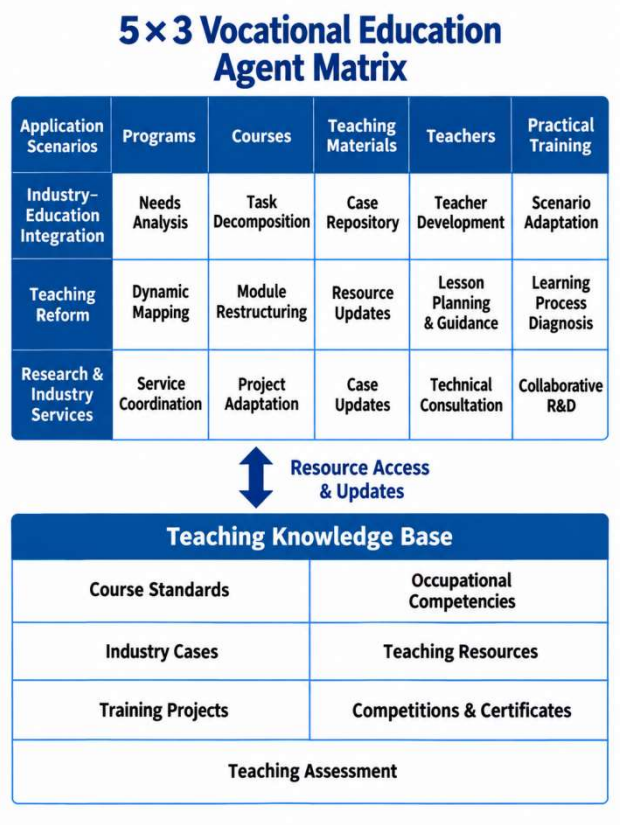


Figure 1. Vocational Education Intelligent Agent Matrix Comprising Five Key Teaching Elements and Three Application Scenarios

The industry–education integration scenario is responsible for introducing industrial demands, occupational standards, and engineering projects, primarily addressing the transmission of information between educational provision and industrial development. The teaching reform scenario transforms these inputs into training objectives, curriculum modules, learning resource packages, and practical training tasks. The research and social service scenario, through teachers' participation in

technological research and development, enterprise consulting, and project delivery, feeds new business problems and technological experience back into teaching.

The three scenarios are sequentially connected through demand input, instructional transformation, and experience feedback, enabling the five key teaching elements to be updated on the basis of shared information and evidence.

3.1.1 Generative AI-Empowered Dynamic Mapping between Industrial Demands and Training Objectives

Starting from industrial demands and occupational tasks, a dynamic mapping mechanism of "industrial demands–occupational competencies–training objectives–curriculum system" is established. By collecting job-posting information, enterprise technical documents, and occupational competency standards, an occupational profile encompassing business tasks, knowledge and skills, and professional competencies is constructed. Generative AI is employed to assist in extracting high-frequency tasks, clustering competencies, and analyzing technological associations. Enterprise technical personnel and professional teachers jointly review the results to ensure the authenticity and validity of the demand analysis.

On this basis, occupational competencies are mapped to course learning outcomes to identify missing, duplicated, and poorly sequenced instructional content. For interdisciplinary talent cultivation in the "Information Technology + Shipping" domain, foundational modules such as programming and databases are retained, while content related to data engineering, intelligent applications, and operations and maintenance is dynamically optimized. Industry-specific competencies, including shipping data quality management, industry-specific indicators, and business coordination, are incorporated to continuously align training objectives with industrial demands.

3.1.2 Generative AI-Empowered Transformation of Enterprise Engineering Tasks into Progressive Learning Tasks

A task transformation mechanism of "business problems–occupational tasks–competency objectives–learning activities–assessment evidence" is established. Teachers and enterprise mentors jointly determine project objectives and engineering constraints. Generative AI is then used to assist in task decomposition, difficulty analysis, and task variation design, transforming enterprise engineering tasks into a progression from basic operations to individual tasks and comprehensive projects.

Taking an Automatic Identification System (AIS) data-processing project as an example, the engineering process can be transformed into a sequence of progressive tasks, including "data understanding–anomaly identification–data cleaning–indicator calculation–result verification–service deployment." Each task specifies students' operational requirements, criteria for decision-making, and evidence of learning outcomes. Generative AI can provide task variations and instructional prompts; however, the level of assistance should be gradually reduced to guide students from imitative operations toward independent analysis, thereby enabling the effective transformation of enterprise engineering tasks into instructional activities.

3.1.3 Generative AI-Empowered Development of a Resource System Combining Stable Knowledge with Dynamic Cases

A teaching resource system integrating "foundational knowledge + dynamic cases + intelligent assistance" is constructed. Foundational resources focus on relatively stable content, such as data structures, processing principles, and interface specifications, providing students with an essential knowledge base. Dynamic cases are derived from enterprise projects and typical business scenarios and are presented in the form of task packages, datasets, and fault cases to reflect changes in industrial technologies in a timely manner.

Generative AI is used to assist in case adaptation, code annotation, task variation, and error explanation, thereby improving the efficiency of resource development. However, all AI-generated

content must undergo teacher review and technical verification. Dynamic cases should be labeled with information such as version, applicable environment, data source, and update history. Enterprise data must undergo authorization and anonymization procedures, while simulated data should be explicitly identified. In this way, a traceable and continuously iterative teaching resource system can be established.

3.1.4 Generative AI-Empowered Support for Teachers' Instructional Decision-Making and Competency Development

Generative AI support is provided for project decomposition, resource retrieval, learning analytics, instructional design, practical training guidance, and assessment analysis, following the principle of "teacher leadership, intelligent assistance, and evidence-based decision-making." Teachers can examine the basis of AI-generated outputs, modify task parameters, adjust instructional plans, and retain records of key review processes, thereby avoiding excessive dependence on generated results.

Teacher competency development should focus on three areas: technical verification, intelligent instructional design, and data ethics. Teachers should be guided to verify AI-generated content, control the degree of intelligent prompting, and adjust instructional arrangements based on students' learning evidence. Through enterprise-based professional practice, joint school–enterprise lesson preparation, and classroom reflection, changes in enterprise technologies, typical faults, and engineering experience can be transformed into teaching resources, thereby strengthening teachers' capabilities in intelligent teaching and engineering practice guidance.

3.1.5 Generative AI-Empowered Development of Executable and Diagnosable Engineering Environments

An executable and diagnosable training environment integrating data, development, testing, deployment, and operations and maintenance is constructed around authentic engineering projects. The environment incorporates data sources, development tools, version-control systems, testing services, and logging systems, while containerization technologies are employed to achieve standardized environments and rapid recovery. Generative AI assists with configuration checking, technical information retrieval, and fault diagnosis. For modifications involving critical configurations or system deployment, access control and human confirmation are required.

The engineering environment incorporates abnormal scenarios such as missing data, incorrect configurations, interface changes, and failed tests, guiding students through the complete engineering process of "problem identification–cause analysis–modification verification–testing and confirmation." Intelligent assistance is gradually introduced or expanded according to students' competency levels. Teaching systems remain isolated from actual business systems, enabling students to develop engineering practice skills, problem-diagnosis capabilities, and awareness of security responsibilities within a safe and controllable environment.

3.2 Generative AI-Empowered Implementation of Project-Based Teaching

3.2.1 Implementing Teacher–Agent–Student Collaborative Teaching

As illustrated in Figure 2, this study establishes a collaborative teaching structure in which teachers provide leadership, intelligent agents provide support, and students engage in practical learning. Teachers are responsible for setting learning objectives, adjusting task difficulty, reviewing learning resources, organizing classroom activities, and conducting final assessments. Intelligent agents undertake tasks such as information organization, resource generation, practical training assistance, and process recording. Students are responsible for understanding requirements, implementing solutions, verifying results, and reflecting on and improving their work. The three parties collaborate around project tasks, embedding intelligent support throughout the learning process while ensuring students' substantive participation in key cognitive activities and engineering practice.

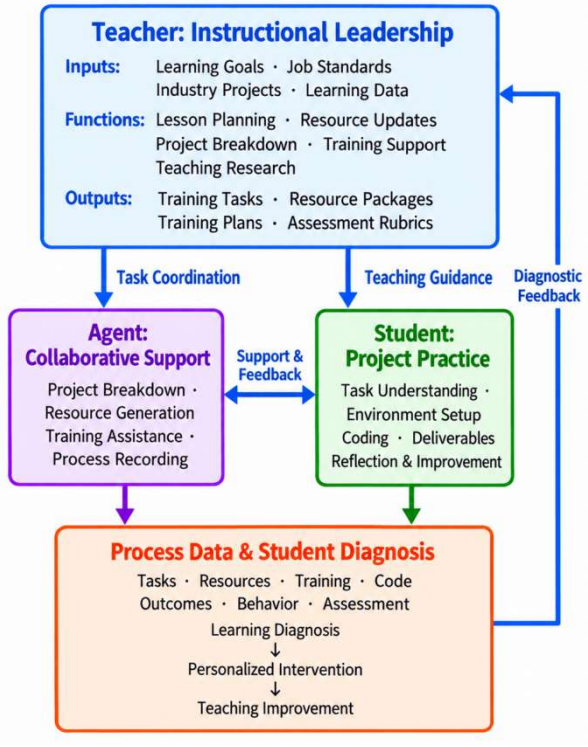


Figure 2. Teacher–Agent–Student Collaborative Teaching Structure

Before class, teachers use a teacher intelligent-agent workspace to decompose projects, integrate resources, and design instruction based on curriculum standards, occupational requirements, enterprise projects, and learning analytics. This process generates reviewed teaching task packages, resource packages, practical training plans, and assessment rubrics. During class, students carry out environment deployment, code development, and testing and verification according to task requirements. Intelligent agents provide assistance in information retrieval, step-by-step guidance, and error analysis, while teachers provide targeted instruction on business understanding, technical challenges, and common misconceptions. After class, student work, practical training records, and assessment feedback are integrated to generate diagnostic recommendations, providing evidence for subsequent task adjustment and individualized guidance.

Collaborative teaching should establish appropriate boundaries for intelligent assistance according to learning objectives. Students should complete basic knowledge acquisition and key skill-training activities independently, while reasonable use of intelligent agents may be permitted during comprehensive project activities. Students should also explain the rationale for adopting AI-generated content, the verification process, and any modifications made. Intelligent agents should prioritize providing conceptual guidance and localized examples rather than complete solutions, progressively guiding students toward independent problem solving. In this way, human–AI collaboration can support the development of professional competencies while preventing complete answers from replacing necessary thinking and practical operations.

3.2.2 Generative AI-Empowered Teaching through Authentic Smart Shipping Projects

For interdisciplinary talent cultivation in the "Information Technology + Shipping" domain, authentic smart shipping projects are introduced through school–enterprise collaboration to establish a project-based teaching mechanism of "authentic business context–occupational tasks–learning tasks–project outcomes." Teachers and enterprise mentors jointly identify business requirements, occupational competencies, and engineering specifications embedded in projects. Generative AI is used to assist in task decomposition, difficulty stratification, and resource matching, thereby transforming authentic enterprise projects into progressive tasks that correspond to students' cognitive development and

instructional conditions. This approach preserves the authenticity of engineering practice while avoiding the simple replication of enterprise projects.

Taking an Automatic Identification System (AIS) data-processing project as an example, teaching activities are organized around data understanding, anomaly identification, data cleaning, indicator calculation, result presentation, and deployment and delivery. Students begin by analyzing data fields and business requirements and then complete solution design, program development, testing and verification, and project delivery. Generative AI is integrated throughout project implementation to assist with technical information retrieval, code analysis, fault diagnosis, and solution optimization. However, students are required to independently complete critical decisions concerning business rules, technology selection, and interpretation of project outcomes.

The final project is comprehensively assessed through deliverables including source code, execution results, testing reports, and business analysis. This approach promotes a shift from merely "completing tasks" toward "solving authentic problems," thereby strengthening students' practical engineering competencies and their ability to apply ICT technologies in real-world business contexts.

3.2.3 Generative AI-Empowered Student Development Diagnosis Based on Multi-Source Evidence

To support the development of students' competencies throughout the learning process, multiple sources of learning evidence—including task records, practical training logs, code versions, project outcomes, learning behaviors, and assessment feedback—are integrated to establish an assessment mechanism of "learning evidence–competency indicators–development diagnosis." Course objectives are broken down into competency indicators covering knowledge understanding, engineering skills, and professional competencies. These indicators are then associated with specific forms of learning evidence to construct dynamically updated student competency profiles, providing a basis for accurately identifying learning difficulties and implementing individualized support.

Generative AI assists in organizing learning evidence, identifying error patterns, and generating diagnostic recommendations. However, students' competencies should not be assessed on the basis of isolated indicators such as the number of AI interactions or lines of code generated. Teachers should make comprehensive judgments by considering classroom performance, project defense, and the quality of project outcomes.

Differentiated interventions can then be implemented according to the identified problems. Students with insufficient conceptual understanding can be provided with foundational learning resources; those with weak operational skills can receive targeted training; and those with insufficient comprehensive application capabilities can be assigned transfer-oriented tasks. The effectiveness of these interventions should subsequently be evaluated through students' performance in later learning activities, thereby forming a continuous cycle of evidence collection–diagnosis–intervention–verification.

4 CONCLUSION

The rapid development of Generative AI and intelligent agents is reshaping the occupational structure, work practices, and competency requirements of the ICT industry. Higher vocational ICT education therefore needs to shift from traditional knowledge- and skill-oriented provision toward dynamic alignment with industrial demands and the cultivation of human–AI collaborative competencies. In response to challenges including the lagging alignment of program structures, insufficient transformation of authentic engineering tasks, delayed updating of teaching materials, inadequate digital-intelligence competencies among teachers, and the disconnect between practical training environments and enterprise workplaces, this study follows the reform requirements for the five key teaching elements of vocational education—programs, curricula, teaching materials, teachers, and practical training. A "5×3" vocational education intelligent agent matrix is constructed, together with

five reform pathways: dynamic mapping of industrial demands, transformation of enterprise engineering tasks, development of dynamic teaching resources, support for teachers' instructional decision-making, and construction of engineering-oriented training environments.

Furthermore, the study promotes the implementation of these reforms through teacher–agent–student collaborative teaching, authentic smart shipping project-based teaching, and multi-source evidence-based student development diagnosis. The proposed framework provides a practical approach to the systematic reform of key teaching elements in higher vocational ICT education through Generative AI and offers a new implementation pathway for cultivating interdisciplinary skilled talents in the "Information Technology + Shipping" domain. As Generative AI continues to evolve from individual tools toward multi-agent collaboration and from content generation toward complex task execution, vocational ICT education will become increasingly scenario-based, intelligent, and dynamic. Future research should further strengthen school–enterprise collaboration and improve mechanisms for dynamically updating industrial demands, occupational standards, and talent cultivation objectives. Intelligent agent matrices should be expanded from instructional assistance to professional development, technological research and development, and social services. Cross-disciplinary and cross-domain collaboration among intelligent agents should also be strengthened to improve their capacity to support complex engineering tasks and authentic business scenarios. At the same time, greater attention should be paid to data security, intellectual property, algorithmic ethics, and norms governing the use of intelligent technologies, with the aim of establishing explainable and traceable human–AI collaboration mechanisms. Through further validation across different vocational programs and authentic engineering projects, the proposed reform model can be continuously refined, enabling Generative AI to become an important driver of quality improvement in higher vocational ICT talent cultivation and the digital transformation of vocational education.

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