

GenAI Empowering Vocational Education Ecosystems: A Digital Innovation Ecosystem Theory Perspective

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Abstract: The rapid development of generative artificial intelligence (GenAI) is propelling vocational education from instrumental digitalization toward ecological reconstruction. Existing research has largely focused on GenAI's value in teaching assistance, resource generation, and learning support, but has insufficiently addressed how it reshapes multi-actor relationships, organizational structures, and governance logic within vocational education. This paper introduces the Digital Innovation Ecosystem (DIE) theory and analyzes the intrinsic mechanisms through which GenAI empowers the ecological reconstruction of vocational education across five dimensions: innovation actors, innovation structure, innovation institutions, innovation functions, and innovation evolution. The study argues that GenAI, as an intelligent agentic element with connecting, translating, and coordinating functions, drives teachers, students, enterprises, industry organizations, and platform institutions to form a new type of human-machine co-creation collaborative relationship. By interconnecting data infrastructure, linking intelligent platforms, and coordinating task networks, GenAI propels vocational education's structure from resource aggregation to process coupling. Relying on data governance, algorithmic ethics, and human-machine coordination institutions, it ensures safe and orderly technology application, and releases educational value through practical knowledge translation, higher-order competency generation, and industry-education demand matching. At the same time, GenAI's empowerment of vocational education still faces real impediments: insufficient actor collaboration, loose structural connections, lagging institutional supply, constrained functional release, and weak evolutionary mechanisms. Accordingly, this paper proposes five practical pathways: layered activation of actor participation to resolve the coordination deficit; a 'small but precise' strategy to advance data infrastructure construction; establishing a 'graded and scenario-based' institutional governance framework; reconstructing an embodied experience-oriented task resource system through 'human-machine collaborative practical training'; and building a progressive evolutionary mechanism of 'small-step piloting - process reengineering - reciprocal co-creation'.

Keywords: Vocational Education, Generative Artificial Intelligence, Education Ecology, Digital Innovation Ecosystem Theory.

1. Introduction

"The current new round of technological revolution and industrial transformation is gathering momentum. Artificial intelligence technology is accelerating its iteration and ushering in explosive development, profoundly transforming the ways humanity produces and lives, the modes of knowledge supply, and the paradigms of scientific research and innovation." [1] Since 2022, generative artificial intelligence systems such as ChatGPT and DeepSeek have propelled transformations in teaching and learning, [2] exerting a profound influence on the future of vocational education [3] and imposing higher demands on pedagogical ecosystems. [4] Existing research has largely approached this topic from the perspectives of instructional application, the impacts on vocational education, practical challenges, and coping strategies. While this body of work has effectively revealed how GenAI enhances instructional efficiency and empowers educational reform, it remains insufficient in explaining how GenAI changes relationships among schools, enterprises, platforms, teachers, and students - and how it drives the overall evolution of the vocational education ecosystem. Based on this observation, this paper introduces the Digital Innovation Ecosystem (DIE) theory and analyzes the intrinsic mechanisms through which GenAI empowers the vocational education ecosystem across five dimensions - actors, structure, institutions, functions, and evolution - before proposing practical pathways, [5] with the aim of

providing theoretical explanation and practical reference for the high-quality development of vocational education in the intelligent era.

2. Theoretical Framework of the Digital Innovation Ecosystem

The Digital Innovation Ecosystem (DIE) theory emphasizes multi-actor collaboration, resource sharing, open innovation, and ecological evolution under digital technology conditions. It provides an analytical perspective for understanding how GenAI transcends the properties of traditional teaching tools, becomes embedded in diverse scenarios of vocational education, and reconstructs actor relationships. Accordingly, this paper constructs an analytical framework across five dimensions: innovation actors, innovation structure, innovation institutions, innovation functions, and innovation evolution.

Innovation actors are the basic units that conduct innovative activities and create value within the digital innovation ecosystem. In the digital context, users participate as innovation actors in value co-creation processes; the emergence of digitized actors and the digital transformation of traditional actors jointly reshape the ecosystem's actor composition and interaction modes. [5] In the GenAI-empowered vocational education ecosystem, educational actors are no longer limited to traditional human participants. These include teachers and students who are undergoing

identity transformation and returning to their core educational roles, as well as governmental, enterprise, and industry organizations that provide computing power and industry data. The most central variable is the introduction of "intelligent agentic actors" possessing autonomous interaction and generation capabilities.

Innovation structure refers to the relational network formed among actors, resources, and activities within the digital ecosystem, which determines the system's internal connectivity density and collaborative efficiency. The digital innovation ecosystem optimizes and reconstructs the overall structure of traditional innovation ecosystems across four dimensions - boundaries, bottlenecks, networks, and modules - by converging and blurring multiple boundaries, relying on scalability to break development bottlenecks, leveraging self-growth to strengthen inter-actor network connections, and employing modularity to refine the layered architecture. In the GenAI-empowered vocational education ecosystem, the structure is reshaped into three tightly coupled layers: at the bottom is the "data infrastructure layer" aggregating high-quality industry corpora; in the middle is the "intelligent platform connectivity layer" breaking physical boundaries between schools and enterprises; and at the top is the "task network collaboration layer" oriented by real industrial production logic, reorganizing curricula and practical training around vocational tasks.

Innovation institutions are the rule foundation for the stable operation of the digital innovation ecosystem, primarily used to regulate actor behavior, resource flows, and value distribution. The introduction of digital elements and digital technology brings institutional issues such as digital rights confirmation, the digital divide, infrastructure governance, and platform governance. In the GenAI-empowered

vocational education ecosystem, institutional development focuses on three levels: first, a "data governance institution" clarifying the ownership and transfer rules of large model training data in the context of industry-education integration; second, an "algorithmic ethics institution" guarding against algorithmic bias, model hallucination, and machine-induced risks; and third, a "human-machine coordination institution" delineating the boundaries of human and machine responsibilities throughout the entire instructional process. These three types of institutions collectively provide basic guarantees for the transition of GenAI from being usable to being used well.

Innovation functions represent the concentrated manifestation of value release in the digital innovation ecosystem, reflecting the actual effectiveness of the system in resource allocation, knowledge production, and value creation. Digital elements, digital technology, digitized user identities, and digital multilateral platforms can deepen ecosystem functions, causing them to exhibit characteristics of digitization, economies of scale, servitization, as well as integration and flexibility. In the GenAI-empowered vocational education ecosystem, the first function to be activated is the "practical knowledge translation function": relying on powerful cross-modal comprehension to transform tacit operational experience - which industry experts could only implicitly grasp - into explicit resources. The second is the "higher-order competency generation function": cultivating students' capacity to cope with uncertainty through open and dynamic tasks. The third is the "industry-education demand matching function": perceiving industrial technology iteration in real time through data flows to achieve dynamic alignment.

Table 1. Analytical Framework of GenAI Empowering Vocational Education Based on DIE Theory

Dimension	DIE Classification of GenAI	Ecological Composition of GenAI-Empowered Vocational Education
Innovation Actors	Intelligent Agentic Actors Core Educational Actors Cross-boundary Collaborative Actors	GenAI embedded as intelligent agent throughout teaching processes; Teachers shift to designer and guide roles; Government, enterprises, and platform institutions reorganize collaborative relationships
Innovation Structure	Data Infrastructure Layer Intelligent Platform Connectivity Layer Task Network Collaboration Layer	Industry corpora and multimodal datasets; Platform shifts from resource storage to process integration; Curricula and assessment reorganized around real vocational tasks
Innovation Institutions	Data Governance Institution Algorithmic Ethics Institution Human-Machine Coordination Institution	Data rights confirmation, circulation rules, and security boundaries; Prevention of algorithmic bias and content auditing; Human-machine responsibility delineation and application boundaries
Innovation Functions	Practical Knowledge Translation Function Higher-Order Competency Generation Function Industry-Education Demand Matching Function	Tacit practical knowledge made explicit; Human-machine interaction driving critical thinking; Dynamic matching of industrial job demand changes
Innovation Evolution	Scenario Embedding Stage Process Restructuring Stage Ecological Co-Creation Stage	Partial assistance → System embedding → Data feeding back to model iteration

Innovation evolution refers to the dynamic process of continuous development in the digital innovation ecosystem,

emphasizing the system's ongoing adjustment through the dynamic evolution of interconnected elements. Innovation ecosystems are not static structures but continuously enter new stages of development through sustained coupling; the embedding of digitization further accelerates this process, driving ecosystem upgrading and deepened application. In the GenAI-empowered vocational education ecosystem, the initial stage is the "scenario embedding stage" in which artificial intelligence is used as a lesson-preparation or writing assistance tool; the intermediate stage is the "process restructuring stage" in which the core business processes of teaching, learning, and assessment are deeply intelligentized; and the final stage is the "ecological co-creation stage" in which teachers and students produce high-quality human feedback within real workflows, which in turn optimizes and iterates the underlying industry large model.

3. Intrinsic Mechanisms of GenAI-Empowered Ecological Reconstruction of Vocational Education

Drawing on this theoretical perspective, this section analyzes the intrinsic logic through which GenAI - once embedded in the vocational education ecosystem - drives transitions from technological application to ecological reconstruction, examining the mechanisms of actor collaboration, structural coupling, institutional construction, functional release, and feedback evolution.

3.1. Embedding of Intelligent Agentic Elements Drives Human-Machine Co-Creation Among Core Educational Actors and Cross-Boundary Collaborative Actors

The embedding of intelligent agentic elements transforms actor relationships in vocational education from traditional inter-human collaboration to human-machine co-creation. GenAI is not an educational actor fully equivalent to human actors such as teachers and students; rather, it is an intelligent agentic element that plays roles of connection, translation, and coordination in teaching design, learning support, practical training feedback, and resource generation. Once it enters vocational education, the original interaction relationships centered on teachers, students, and enterprise mentors are reorganized. Educational activities are no longer merely the transmission of knowledge and the guidance of experience among human beings, but form a collaborative network in which teachers, students, and intelligent systems all participate.

The reconstruction of core educational relationships transforms the role division between teachers and students from one-way transmission to bidirectional generation. In traditional vocational education, teachers primarily bore responsibility for knowledge instruction and skill demonstration, while students were largely positioned as receivers of knowledge and imitators of operations. After GenAI's embedding, teachers must transition from pure knowledge transmitters to designers of instructional scenarios, guides of learning processes, and auditors of generated outputs. Students, too, are no longer merely passive recipients of training but engage in questioning, comparing solutions, verifying results, and reflecting on corrections in their interactions with intelligent systems. The pedagogical

relationship thus shifts from 'teacher lectures - student receives' to a new form of 'teacher guides - intelligent support - student constructs.'

The reorganization of cross-boundary collaborative relationships transforms the roles of governments, enterprises, industry organizations, and platform institutions from segmented participation to collaborative governance. As GenAI enters vocational education, the talent cultivation process becomes increasingly dependent on the collaborative supply of data, standards, models, and real-world tasks. Governments not only fulfill policy-making and regulatory responsibilities but must also participate in rule supply, public platform construction, and ecological governance. Enterprises no longer merely serve as employers and practical training partners but participate more deeply in curriculum development, project supply, and educational resource construction. Industry organizations need to promote the dynamic updating of vocational standards, skills standards, and curriculum standards. Platform institutions shift from technology service providers to important nodes for data connectivity, model support, and organization of the learning process. As a result, vocational education gradually forms a new ecosystem featuring multi-actor participation, collaborative resource production, dynamically updated standards, and jointly governed processes.

3.2. Interconnection of Data Infrastructure Propels Vocational Education Structure from Dispersed Operation to Multi-Layer Coupling

The interconnection of data infrastructure transforms the dispersed data resources in vocational education into structural resources that can serve talent cultivation. The data required for vocational education is markedly composite, encompassing both in-school instructional materials, learning process data, and assessment feedback data, as well as multi-modal data such as industry standards, job competency requirements, production processes, and operational traces. In the past, this data was scattered across schools, enterprises, platforms, and industry organizations and difficult to incorporate into curriculum construction, practical training organization, and assessment improvement. GenAI, with its capabilities for semantic understanding, multi-modal parsing, and knowledge organization, can integrate and transform fragmented data, enabling smoother connections among industry data, instructional data, and practical training data.

Intelligent platform connectivity transitions vocational education from resource aggregation to process integration. Existing vocational education platforms have largely emphasized resource storage, course display, and learning services - primarily solving the question of 'where are the resources' without adequately addressing 'how resources enter the educational process.' After GenAI's embedding, platforms are no longer merely resource repositories but become mediating hubs connecting actors, data, models, and tasks. Learning support can be dynamically adjusted according to students' states, practical training feedback can be embedded in operational processes, and course development can be promptly optimized in response to changes in job competency requirements. Platform functions thus shift from static resource supply to full-process support encompassing teaching, learning, practical training, and assessment.

Task network collaboration transforms vocational education structure from knowledge-unit organization to

work-process organization. The core advantage of vocational education lies in linking the learning process with real vocational tasks, yet in practice course content, practical training projects, and job requirements are often disconnected. GenAI can use complex vocational problems as starting points, transform enterprise projects into project-based curricula, decompose craft processes into progressive practical training tasks, and embed job competency standards in assessment rules. The operational data, interaction records, and reflective content that students generate in completing tasks can in turn be used for learning diagnosis and instructional improvement. Vocational education thus forms a multi-layer coupled structure grounded in data interconnection, mediated by intelligent platforms, and oriented toward task collaboration.

3.3. Collaborative Improvement of Institutional Rules Propels GenAI Application from Technical Usability to Safe Trustworthiness

The improvement of data governance institutions transforms multi-source data flows from empirical negotiation to rule-based constraint. GenAI's empowerment of vocational education requires drawing on multi-source information such as industry corpora, job standards, instructional data, and practical training records, and these data often involve issues of intellectual property ownership, student privacy, trade secrets, and circulation security. Without clear rules, even if schools and enterprises have a willingness to cooperate, it is difficult to share data due to unclear responsibilities and unspecified risks. It is therefore necessary to clarify rules for data rights confirmation, open boundaries, access permissions, and security responsibilities, promoting orderly flows of industry-education data on a compliant basis and avoiding data misuse, privacy breaches, and interest imbalances.

The establishment of algorithmic ethics institutions transforms GenAI's participation in instructional assessment from result dependency to controllable risk. Large language models may produce problems such as algorithmic bias, knowledge distortion, and result misrepresentation during content generation, learning diagnosis, and assessment feedback. Vocational education directly concerns students' skill formation and career development; if model outputs enter teaching and assessment processes without review, they may affect knowledge transmission, skills judgment, and student growth. It is therefore necessary to establish mechanisms for algorithm review, content verification, and risk classification, with human review required for high-risk instructional scenarios to prevent technological judgment from replacing teachers' educational judgment.

The improvement of human-machine coordination institutions transforms the application of intelligent technology from blurred boundaries to clear responsibilities. After GenAI enters vocational education, new collaborative relationships are formed among teachers, students, enterprise mentors, and intelligent agentic elements, also bringing problems of unclear responsibility assignment, strengthened reliance on feedback, and excessive use of technology. Institutional design should clearly define GenAI's scope of application in instructional design, learning support, practical training guidance, and assessment diagnosis, specifying which stages it may assist in and which stages must be controlled by teachers or enterprise mentors. Only by

clarifying application boundaries can risks be prevented, such as weakening of skills training, distortion of assessment results, and deviation from educational purposes.

3.4. Accelerated Translation of Practical Knowledge Propels Vocational Education Functions from Resource Supply to Competency Generation

Practical knowledge translation transforms industry experience from individual possession to systemic sharing. Vocational education has a distinctive practical character, and its key resources often derive from the on-site experience of industry experts and technical specialists. This experience is highly bound to specific work contexts, frequently manifesting as tacit knowledge that is difficult to express and disseminate directly. Traditional digitization methods have largely remained at the level of operational videos, textual instructions, and resource storage, falling short in adequately presenting the processes of experiential judgment and contextual response. GenAI, through its multi-modal comprehension and logical analysis capabilities, can decompose complex experience into task scripts, operational procedures, case scenarios, and simulation models, transforming practical knowledge into digital resources that are shareable, trainable, and assessable.

Higher-order competency generation transitions vocational education from simple skills training to complex problem-solving. After GenAI enters practical training scenarios, it can more vividly present complex vocational problems to students through scenario simulation, process deduction, and interactive feedback. In fault scenarios and task settings generated by artificial intelligence, students must continuously analyze problems, compare solutions, verify results, and revise judgments. This process not only consolidates professional skills but can also promote the development of critical thinking, systemic analytical abilities, and vocational judgment capacities. Vocational education's educational function thus extends from operational training to the cultivation of complex competencies.

Industry-education demand matching transitions talent cultivation from fixed supply to dynamic matching. Current industrial technology updates are rapid, job structures and competency requirements are continuously changing, yet vocational colleges' curriculum updates often lag behind. GenAI can, through data connectivity, track changes in job competencies on the industry side and record students' growth processes on the learning side, implementing matching between the two through semantic analysis. This helps schools promptly adjust professional development and course content, and can also provide students with learning pathways and competency certification support more closely aligned with industrial development needs. Vocational education's talent cultivation model thus gradually transitions from preset cultivation to dynamic adaptive cultivation.

3.5. Deepening of Feedback Mechanisms Propels Vocational Education Ecosystems from Localized Application to Self-Renewal

Scenario embedding enables GenAI to transition from external technical tool to specific instructional stages. The empowerment of vocational education by GenAI typically first occurs in low-risk scenarios such as lesson preparation,

answering questions, material generation, and learning assistance. At this stage, technology primarily undertakes supportive tasks, improving the efficiency of instructional resource supply and enhancing the effectiveness of student learning support. However, this type of application still largely remains at the level of individual stages and has not yet changed the basic relationships among curricula, practical training, and assessment.

Process restructuring transitions GenAI from localized assistance to core business reengineering. When GenAI enters core processes such as curriculum development, task design, practical training guidance, and instructional assessment, technological application is no longer merely external support but begins to change the organizational mode of vocational education's internal processes. Course content can be promptly adjusted in response to job changes, practical training guidance can be dynamically optimized according to students' performance, and instructional assessment shifts from purely result-based judgment to process analysis. The stages of teaching, learning, practical training, and assessment thus gradually transition from relative dispersion to continuous integration.

Ecological co-creation transitions vocational education from using intelligent technology to participating in the optimization of intelligent systems. The operational processes, learning performance, and task data formed by students in real or simulated vocational tasks can be used in reverse to optimize curricula, practical training, and assessment systems, and can also support the continuous updating of vocational education large models, industry intelligent agents, and assessment intelligent agents. At this point, vocational education is no longer merely an application scenario for GenAI but participates in model optimization and resource reproduction through multi-actor collaboration and data feedback. Vocational education ecosystems thus gradually develop self-optimization and continuous renewal capabilities.

4. Real Impediments to GenAI-Empowered Ecological Reconstruction of Vocational Education

4.1. Insufficient Actor Collaboration: Human-Machine Trust Deficits and Anxiety About Technological Substitution in Cross-Boundary Participation

Actor collaboration is the prerequisite for GenAI's entry into the vocational education ecosystem. Vocational education already relies on multi-party social actors to participate jointly, and GenAI, as an intelligent agent embedded throughout the entire instructional process, further alters the original collaborative relationships. Currently, however, schools, enterprises, teachers, and platform institutions have not yet formed sufficient consensus on the functional boundaries, responsibility attribution, and risk consequences of GenAI, easily generating inadequate human-machine trust and anxiety about technological substitution. As a result, current GenAI applications are largely confined to scattered pilots and partial assistance, and have yet to genuinely enter core educational stages such as curriculum development, practical training guidance, and assessment diagnosis.

First, teachers and students exhibit divergent cognitions of GenAI. Existing research shows that 24% of students regard GenAI as a labor substitute, using AI uncritically in assignments and reports with direct reliance on generated content; 42% of students maintain a skeptical and critical attitude toward answers generated by GenAI.[6] Teachers, on the other hand, concentrate their use of GenAI highly on administrative tasks such as lesson preparation, courseware generation, and question setting, with their thinking, skills, and professional spirit also being affected. [7]Second, the depth of participation by enterprises, industry organizations, and platform institutions is insufficient. Against the backdrop of AI large language models, there exists a phenomenon of "industry cold, education hot" and "joint without depth"; enterprise and industry associations with platform institutions largely remain at shallow project cooperation, with inadequate depth of involvement in school-enterprise collaboration. [8]The rate of cross-enterprise data sharing in the vocational education sector is low, and there are uneven distributions of computing resources along with regional disparities. [9]Third, the ecological positioning of intelligent agentic actors remains unclear. Viewing GenAI merely as a tool underestimates its influence on task organization and learning feedback; overemphasizing its subjectivity, on the other hand, may lead to outsourcing educational judgment. Skill formation in vocational education relies on physical operation, on-site experience, and contextual judgment; GenAI can provide solution suggestions and feedback support but cannot replace teachers' professional oversight, enterprise mentors' judgment, and students' direct hands-on training. Therefore, the questions of where intelligent agents should assist, where they should participate, and where they should withdraw require the formation of clear boundaries.

4.2. Loose Structural Connections: Deeply Entrenched Industry-Education Barriers and Scarcity of High-Quality Industry Training Corpora

Structural connectivity is the foundational condition for GenAI-empowered ecological reconstruction of vocational education. The state has clearly proposed promoting deep application of artificial intelligence in areas such as educational governance, talent supply-demand matching, learning process assessment, and multi-modal data analysis, as well as advancing the interconnection of educational platforms, resources, and services.[10] However, from a practical standpoint, stable connections have yet to be formed among vocational education's data infrastructure, intelligent platforms, and task collaboration networks. Between the school education system and the industrial production system, difficulties in data circulation, insufficient platform interconnection, and unsmooth task linkage still persist.

First, the data infrastructure layer suffers from the compounded defects of an unstable foundation and data silos. GenAI's application in vocational education scenarios depends largely on professional corpora and industry data, yet the current data foundation is not yet solid. On one hand, higher vocational colleges lack top-level planning in data construction with non-unified data planning and standard interfaces; [11]on the other hand, data-opening mechanisms between schools and enterprises remain incomplete, with the security responsibilities and usage boundaries of industry data insufficiently clear, making it difficult for high-quality industry data to naturally and safely enter teaching processes,

thereby exacerbating data silos. Second, the intelligent platform connectivity layer faces protocol barriers and trust issues. After artificial intelligence enters social governance, different platforms still exhibit non-uniform interface standards and difficulties in system integration. Meanwhile, stable data mutual-trust mechanisms are also lacking among different actors. [12]Data redundancy and data gaps at some higher vocational colleges further undermine the operational foundation of platforms. [13]Third, task network collaboration suffers from role distortion and lagging assessment. An important objective of vocational education ecosystem reconstruction is to make the learning process more closely aligned with real work processes. In practice, however, course instruction, skills competitions, instructional assessment, and enterprise tasks are often managed by different systems. Additionally, current vocational education assessment methods also present certain problems: some assessment systems over-emphasize fixed outcomes and quantitative indicators while neglecting students' developmental processes and growth in integrated competencies[14].

4.3. Lagging Institutional Supply: Absence of Data Rights Confirmation and Blurred Boundaries of Rights and Responsibilities in Algorithmic Governance

Institutional supply is the basic guarantee for GenAI's safe embedding in the vocational education ecosystem. GenAI not only participates in educational resource generation, learning support, and process assessment, but is also beginning to influence educational governance and decision-making processes. [15]Currently, however, the speed of GenAI application in the vocational education sector has clearly outpaced the speed of institutional development. Relevant institutions still suffer from problems of delayed rules, dispersed content, and insufficient scenario adaptation.

First, the rules for data rights confirmation and circulation remain unclear. Vocational education data sources are complex: learning records generated by students on enterprise virtual simulation training platforms and craft data left behind by industry technical personnel during school teaching processes simultaneously possess both educational and industrial attributes, making it difficult to clarify ownership boundaries. Moreover, data sharing between schools and enterprises still lacks unified data interfaces, format standards, and privacy protection mechanisms - so even when all parties are willing to share data, actual sharing still encounters numerous obstacles related to technical integration, security review, and responsibility assignment. Second, algorithmic ethics mechanisms are incomplete. During GenAI's application in education, data security and algorithmic ethics risks persist. In the processes of data collection, storage, and use, privacy breaches may occur. GenAI may also create an 'information closure' phenomenon that affects students' exposure to diverse knowledge, thereby disrupting data ecosystem balance. [16]During GenAI's generation process, algorithmic discrimination may manifest, specifically regarding gender, race, and other dimensions. There are also legal supporting systems and ethical standard norms that are absent or irregular, and infringement resulting from non-standardized use will ultimately weaken human subjectivity. [17]Third, human-machine coordination and responsibility boundary delineation remain unclear. After GenAI enters vocational education, new collaborative relationships have

been formed among different actors, but the boundaries of responsibilities such as instructional design remain undefined. The absence of defined data privacy boundaries among actors may make it difficult for actors to ensure their control over data. Unclear rights and responsibilities boundaries significantly increase colleges' compliance supervision pressure, requiring additional resource expenditure to manage data ethics and legal risks, raising institutional operating costs and constraining the intelligent and high-quality development of vocational education[18].

4.4. Constrained Functional Release: Gaps Between Resource Transformation, Scenario Application, and Educational Effectiveness

Functional release is the key to verifying the effectiveness of GenAI's empowerment of vocational education. Its value lies not in the embedding of the technology itself but in whether it can genuinely improve practical teaching and promote industry-education demand matching. Influenced by factors such as the complexity of vocational education contexts, the gradual nature of competency formation, and high requirements for practical transfer, GenAI applications are prone to transformation deviations and insufficient effectiveness.

First, there is insufficient practical knowledge translation and embodied experience. Practical knowledge in vocational education is not merely operational steps but also encompasses physical perception, experiential judgment, and contextual response. When GenAI transforms industry on-site experience into instructional resources, it easily simplifies skills that require repeated operations and on-site understanding into process descriptions, graphic demonstrations, or standard answers. Students may appear to understand operational methods but have not truly formed the perceptual experience and judgment capacity required in vocational actions. GenAI's development has increased people's knowledge acquisition capacity, yet the contempt for knowledge learning that GenAI exacerbates will ultimately lead to dual losses in knowledge mastery and competency cultivation. [19]Second, higher-order competency generation and cognitive process support are insufficient. Higher-order competency generation is an important goal of GenAI-empowered vocational education; yet in practice, on one hand, it has been pointed out that transferring higher-order thinking to GenAI leads to loose cognitive structures and obstructed internalization of independent thinking ability and practical knowledge, directly causing the implicit skill transmission of 'learning by doing' to lose effectiveness. [20]On the other hand, excessive reliance on GenAI's 'one-click generation' easily undermines students' abilities to decompose problems and identify errors - since the formation of higher-order competencies in vocational education originates precisely from repeated trial-and-error, contextual judgment, and continuous correction. If students hand over analytical processes and solution judgments to GenAI, technological dependence forms, even bringing the risk of 'de-skilling.' In short, the more machine intelligence is front-loaded, the more students' metacognitive abilities, critical reflective capacities, and autonomous decision-making abilities tend to be compressed, making higher-order competency generation even harder to genuinely achieve. Third, industry-education demand matching and regional demand identification are insufficient. GenAI can help vocational education bridge

information barriers between industry and education and improve the precision of talent supply-demand matching. However, from a practical standpoint, industrial technology updates are increasingly rapid, and job structures and skills requirements continue to change. By comparison, vocational colleges' talent cultivation plans, curriculum standards, and instructional resource construction often still face lengthy update cycles. This means that even if schools have already adjusted talent cultivation based on data projections, when actual implementation occurs, they may already face new job changes, keeping vocational education in a perpetual state of 'catching up with industry changes.' Moreover, vocational education faces demands that extend beyond macroeconomic industry trends. Vocational colleges must place greater emphasis on serving local industrial clusters and regional enterprise job requirements - especially those of small and micro enterprises - and these demands are highly contextual and dynamic, rarely conforming to uniform standards. Solely relying on generic internet data or macro industry reports makes it extremely difficult to accurately identify genuine job requirements.

4.5. Weak Evolutionary Mechanisms: Fragmented Application Scenarios and Absent High-Quality Human Feedback Mechanisms

Innovation evolution is the fundamental driving force behind whether GenAI's empowerment of vocational education ecosystem reconstruction can continue to deepen. Currently, more than 10% of vocational colleges have begun constructing case resources, and more than 30% have taken concrete action.[21] Overall, however, the integration and optimization of exemplary resources remain at an early stage. A sustained evolutionary mechanism - progressing from application feedback to process optimization, then to model iteration and ecological co-creation - has yet to be formed. Consequently, although GenAI has entered vocational education scenarios, it has not truly transformed into an endogenous driving force propelling ecosystem self-renewal.

First, scenario embedding and process integration are insufficient. Currently, GenAI applications in vocational education are mostly at the stage of technical application as tool and means, with a considerable gap from the educational goal of achieving personalized learning and precision teaching. This elementary-stage use makes it difficult for scenario embedding to transform into process restructuring. Curricula, practical training, assessment, and enterprise tasks still belong to different systems, and the instructional resources, learning data, and assessment feedback generated by GenAI find it difficult to flow continuously among different stages. GenAI plays an assistive role in individual scenarios but has difficulty driving the integrated reconstruction of teaching, learning, training, and assessment. Second, process restructuring conflicts with organizational inertia. The key to GenAI's empowerment of vocational education ecosystem evolution lies in its capacity to drive systemic restructuring of core business processes such as curriculum, practical training, assessment, and industry-education collaboration. However, the elements of curriculum, practical training, and assessment in vocational colleges are actually managed by different departments; consequently, once GenAI enters some stages, it naturally integrates into existing processes. Organizational inertia thus weakens the depth of process restructuring, making it difficult to advance

to the genuine breakthrough of transitioning from tool embedding to process reengineering, leaving the ecosystem evolution without adequate organizational vehicles. Third, ecological co-creation and feedback mechanisms are incomplete. Ecological co-creation is the advanced stage of GenAI-empowered vocational education ecosystem evolution, its essence being to create a virtuous cycle of bidirectional feedback and mutual nourishment among educational scenarios, industrial tasks, and intelligent models. In reality, however, vocational colleges tend to introduce and use GenAI while lacking clear mechanisms for directly using instructional practice and practical training data for model optimization. The absence of feedback mechanisms thus causes fractures in ecological evolution, resulting in an ecosystem that is not truly capable of continuous self-renewal.

5. Practical Pathways for GenAI- Empowered Ecological Reconstruction of Vocational Education

5.1. Layered Activation of Actor Participation to Resolve the Human-Machine Co- Creation Coordination Deficit Through Trust Building

The core tensions in resolving insufficient actor collaboration are twofold: first, teachers' anxiety about technological substitution by GenAI has yet to be adequately addressed; second, the participation of enterprises, industry organizations, and platform institutions still remains at shallow project cooperation, and has not formed substantive co-governance. Therefore, the establishment of actor collaboration mechanisms cannot remain at the level of responsibility assignment specifying 'what each party should do,' but must be oriented toward different actors' genuine concerns, designing specific mechanisms that reduce participation costs and strengthen trust foundations.

For the teacher group, GenAI competency cultivation should be embedded into the regular teacher development system of vocational colleges rather than being independently advanced through 'special training.' Schools can set fixed human-machine collaborative instructional design sessions within each semester's teaching research activities, guiding teachers to attempt task design and learning situation diagnosis using GenAI within existing curriculum frameworks, while promptly recording and sharing effective experiences. For teachers who actively explore these approaches, recognition in curriculum construction, educational reform project applications, and professional title review should be provided, enabling teachers who participate in GenAI application reform to feel the value of engagement rather than passively accepting technological advancement. Simultaneously, the scope of GenAI's application in the entire instructional process should be clearly defined: specifying which stages can be assisted, which stages teachers must independently complete, and which stages must be finally reviewed and confirmed by teachers - thereby protecting teachers' professional judgment space from being encroached upon by technology and fundamentally alleviating substitution anxiety.

For enterprises and industry organizations, the current loose cooperation state of 'joint without depth' should be changed by establishing a deep participation mechanism with

'task co-construction' as the nexus. Specifically, schools and enterprises can jointly develop 'vocational task packages' focused on a particular professional direction: enterprises provide real work contexts, job standards, and typical fault cases; teachers are responsible for transforming these into curriculum tasks and practical training projects; and platform institutions provide data interfaces and model support. All three parties clearly define their work content and interest boundaries. This type of task co-construction is more concrete than vague joint cultivation programs and more readily forms sustainable collaborative practices. Additionally, government departments can establish credit records and incentive mechanisms for enterprises' deep participation in vocational education, incorporating enterprises' participation in curriculum development, provision of industry data, and acceptance of practical training students into the industry-education integration evaluation system, gradually enhancing the motivation and stability of enterprise participation.

5.2. Advancing Data Infrastructure Construction with a 'Small but Precise' Strategy to Open Structural Connections Between Industry and Education

The root cause of loose structural connections lies not in parties' lack of willingness to share, but in the absence of data rights confirmation, non-interoperable platform interfaces, and a lack of vehicles for task collaboration - resulting in connections that have 'intentions but no handles.' Therefore, structural reconstruction should not rush to promote large-scale data platform construction but should adhere to the principle of 'small but precise, verifiable, and replicable,' breaking through from key nodes.

Data infrastructure construction should take the professional cluster as the basic unit, led by institutions and with enterprise participation, prioritizing high-employment majors and typical job positions to build 'vocational task corpora.' The content of these corpora should not pursue macroscopic industry data but focus on highly contextual data such as real enterprise work orders, equipment operation videos and annotation records, fault diagnosis processes, and the operational traces of technical specialists. Regarding data ownership, a split-rights mechanism of 'school use rights, enterprise ownership, third-party platform custody' can be adopted, clearly stipulating that data is to be used only for the relevant major's instruction and not for commercial exploitation or third-party training, thereby reducing enterprises' concerns about opening data. Pilot programs should be conducted on a small scale before gradually expanding, to avoid problems of construction without use and data sedimentation resulting from overly large plans.

The transformation of intelligent platforms should focus on 'integrating teaching processes' rather than building a new system. Most vocational colleges already have learning management platforms; the problem is not a lack of platforms but the absence of data interfaces between platforms and GenAI tools, causing students' learning records, practical training performance, and assessment feedback to each remain isolated. Schools can require platform service providers to provide standardized API interfaces, incorporating the usage records of GenAI tools (such as questions posed, generated feedback, and students' correction trajectories) into learning process data, enabling teachers to adjust instruction based on data rather than only on subjective judgment. Such transformation is relatively low-cost yet can

significantly enhance platforms' process support capabilities.

At the task collaboration level, a standard process for 'enterprise task transformation' should be established to resolve the long-standing disconnection between course content, practical training projects, and job requirements. School teachers and enterprise technical personnel can jointly develop 'task transformation templates,' specifying that each practical training project must include: real work background, key operational steps, typical error examples, GenAI-assisted stages, and the delineation between human-completed stages. With a unified template, task resources across different majors and institutions gain the foundation for accumulation and sharing, avoiding the problems of 'duplicated construction and siloed operations' across different schools and majors.

5.3. Establishing a 'Graded and Scenario-Based' Institutional Governance Framework to Clarify Operational Boundaries of Human-Machine Rights and Responsibilities

The problem of lagging institutional supply cannot be resolved merely by issuing macro policies; it further requires vocational colleges to form executable operational rules at the institutional level. Institutional development should distinguish three layers, respectively addressing data governance, algorithmic ethics, and human-machine coordination issues, achieving 'rules to abide by and responsibilities assigned to individuals.'

At the data governance level, vocational colleges can formulate 'Model School-Enterprise Data Sharing Agreements' clearly specifying the following four items: data sources and ownership (distinguishing the owning parties of students' learning data, enterprises' production data, and industry corpora); scope of use (limited only to the relevant major's instruction, not to be used for commercial development or third-party training); security measures (desensitization standards, access logging, permission classification); and breach of contract responsibilities. With such models, individual institutions and enterprises have clear basis when signing cooperation agreements without needing to negotiate from scratch, significantly reducing the institutional costs of initiating cooperation. Regarding student data, it is especially necessary to clarify the ownership of operational records generated in virtual simulation platforms and industry training systems, preventing platform institutions from unilaterally occupying educational data under the pretext of technology service.

At the algorithmic ethics level, a 'human review for high-risk scenarios' mechanism should be established. Specifically, the academic affairs department or major head of the institution should identify which instructional stages constitute 'high-risk scenarios' (such as: skills level certification, practical training grade assessment, safety operation recommendations, mental health support, etc.). For these scenarios, it should be stipulated that GenAI outputs must be reviewed by teachers or enterprise mentors before they can be used, and must not be directly fed back to students or recorded in academic files. For everyday low-risk assistive scenarios (such as lesson preparation material generation, provision of practice questions, etc.), teachers can be authorized to independently decide whether to use GenAI. This 'scenario-graded' governance approach is more

operational than vaguely 'strengthening supervision' and can also avoid obstructing technology application through excessive control.

At the human-machine coordination institution level, 'non-outsourcable baselines' for each actor throughout the entire instructional process should be clarified. Institutions can formulate 'Lists of GenAI Application Boundaries in Instructional Processes' in combination with professional characteristics, specifying stages that teachers must personally complete, stages that students must independently complete, and assistive stages that GenAI may intervene in. This list serves as both institutional guarantee and a basis for teachers to respond to external pressure, providing grounding when facing questions such as 'why not use AI for everything.'

5.4. Reconstructing a Task Resource System Oriented Toward Embodied Experience Through 'Human-Machine Collaborative Practical Training' as the Core

The deep reason for constrained functional release is that the key competencies in vocational education - embodied operational experience and contextual judgment - cannot be directly imparted by GenAI, yet existing application modes tend to transform these competencies into 'readable knowledge,' producing superficial learning where students 'can talk but cannot do.' Therefore, the key to reconstructing task resource systems lies not in having GenAI generate more resources but in designing task structures that can enable GenAI to assist students in 'learning by doing' rather than 'learning by watching.'

In the domain of practical knowledge translation, a three-step workflow of 'experience collection - structural transformation - simulated verification' should be established. In the first step, dual-qualified teachers and enterprise technical specialists jointly carry out 'tacit experience extraction' work: making explicit the judgment processes that experts find difficult to articulate through operational video recording and annotation, 'think-aloud' interviews, and typical fault analysis and review. In the second step, GenAI is used to transform the collected experience materials into structured task scripts, including task background, operational steps, critical judgment nodes, common errors, and correction logic. In the third step, students practice under 'close-to-real' conditions through simulation environments or scenario simulations, with teachers focusing on guiding students' perception and judgment at critical nodes rather than having GenAI serve as the guide throughout. Such a workflow preserves the core value of tacit knowledge transformation while avoiding its simplification into operational instructions.

In higher-order competency cultivation, 'critical human-machine interaction' learning tasks should be designed rather than open-ended generation tasks. Specifically, when teachers assign tasks, students should first independently form preliminary solutions, then obtain another solution or feedback through GenAI, and finally compare the two solutions and provide a discriminating analysis explaining why they adopted or rejected GenAI's suggestions. For assessment, the final output should not serve as the primary basis; rather, the focus should be on examining students' process records of 'how problems were discovered, how model outputs were questioned, how judgments were corrected.' This design makes GenAI a dialogic tool for activating critical thinking rather than an answer provider that substitutes for thinking, effectively curbing the risk of

'outsourcing higher-order competencies.'

In the domain of industry-education demand matching, a 'dynamic demand collection mechanism' oriented toward local industries should be established. Institutions can organize teachers and major heads to conduct at least one targeted enterprise visit each semester to collect the latest job requirements and technological changes from local enterprises; they can sign information-sharing agreements with local industry associations to obtain regional recruitment data and job competency change trends; and they can also establish graduate employment tracking databases, systematically recording graduates' employment directions, job adaptation status, and skills gap feedback, using this data for annual talent cultivation plan revisions. GenAI's role in this mechanism is to conduct semantic comparison and structural organization of the collected multi-source data, assisting teachers in rapidly identifying supply-demand gaps in professional development, rather than relying on macro internet data to make predictions divorced from local reality.

5.5. Building a Progressive Evolutionary Mechanism of 'Small-Step Piloting - Process Reengineering - Reciprocal Co-Creation'

The root cause of weak evolutionary mechanisms is that current GenAI applications lack a systematic advancement pathway from 'localized embedding' through 'process restructuring' to 'ecological co-creation,' and especially the resistance of organizational inertia and the absence of feedback mechanisms cause evolution to stagnate at the first stage. Therefore, the establishment of evolutionary mechanisms must simultaneously address three questions: how to design the advancement pace, how to overcome organizational inertia, and how to open feedback channels.

In terms of advancement pace, an approach of 'small-step piloting, rapid verification, and orderly expansion' can be adopted. At the institutional level, 2–3 courses can be selected each semester as 'human-machine collaborative instructional reform pilot courses,' with participating teachers formulating clear application plans and expected goals. At the end of the semester, instructional effectiveness assessment and experience exchange are organized. The standard for selecting pilot courses is not to choose the most difficult or most problematic ones but to select courses where 'teachers have willingness, students have high cooperation rates, and the course structure is suitable for transformation,' thereby reducing the risk of failure in the first pilot. Successful pilot experience forms a reproducible 'operation case library' for reference by other teachers, promoting reform from individual exploration toward institutional systematic promotion.

In terms of overcoming organizational inertia, process restructuring cannot rely on a single department to advance but requires a collaborative advancement team formed by departments of academic affairs, practical training, teaching research, and quality assessment, with each department's responsibilities in GenAI's embedding of core processes clearly defined. When curriculum development, practical training guidance, and instructional assessment are managed by different departments, GenAI application tends to stop at a particular stage; only when each department acts collaboratively under a unified objective can the integrated reconstruction of 'teaching, learning, training, and assessment' genuinely occur. Institutions can incorporate

'GenAI application advancement status' into annual professional development assessment indicators, using institutional assessment to drive the transformation of organizational inertia across departments.

In terms of building feedback channels, an institutionalized channel for 'educational data directed to model feedback' should be established. Vocational colleges can sign 'data feedback agreements' with platform institutions or large model developers, stipulating that operational records, error-correction trajectories, and expert-annotated data formed by students in real vocational tasks can, after desensitization processing, be used for the iterative optimization of vocational education-dedicated models; institutions can thereby obtain customized model services more closely tailored to their specific major requirements. This data-for-service mechanism incentivizes institutions to continuously accumulate high-quality educational data and promotes GenAI's continuous adaptation and improvement in vocational education scenarios, forming a virtuous cycle. Feedback should not flow only toward the technical layer but should also reversely optimize curricula: systematically organizing the high-frequency errors, cognitive blind spots, and competency gaps exposed in students' GenAI-assisted learning, feeding these back to teachers for curriculum content revision, transforming the curriculum iteration cycle from 'once every three to five years' to a dynamic update rhythm of 'micro-adjustments each semester, systematic optimization each year.'

6. Conclusion

In summary, empowering vocational education with generative artificial intelligence (GenAI) is not merely the insertion of a technical tool, but a systematic reconstruction involving relationships among actors, resource structures, institutional rules, talent cultivation functions, and ecosystem development. Based on digital innovation ecosystem theory, vocational education should uphold talent cultivation as its core mission and remain oriented toward the development of vocational competencies, while promoting a more open and collaborative human-AI co-creation relationship among teachers, students, enterprises, industry organizations, and platform institutions. Going forward, only by continuously improving data foundations, institutional governance, task-based resources, and feedback mechanisms can GenAI move beyond fragmented auxiliary support toward process redesign and ecosystem co-creation, thereby providing sustained momentum for the high-quality development of vocational education.

References

- [1] Yang, Z. K., Wang, J., Wu, D., et al. (2023). Analysis of ChatGPT/generative AI's impact on education and response strategies. *Journal of East China Normal University (Educational Sciences)*, 41(7), 26–35.
- [2] Xu, G. Q., Cai, J. F., Jiang, B. J., et al. (2023). ChatGPT/generative AI and the future of vocational education. *Journal of East China Normal University (Educational Sciences)*, 41(7), 64–77.
- [3] Wang, Y. X., & Hao, T. C. (2025). Generative AI empowering vocational education reform: Challenges and practical pathways. *Education and Vocation*, (4), 14–20.
- [4] Zhang, C., Chen, K. H., & Mu, R. P. (2021). Digital innovation ecosystem: Theoretical construction and future research. *Science Research Management*, 42(3), 1–11.
- [5] Ma, L. P., Zheng, X. R., & Zhou, X. H. (2026). Typological profiles of students using generative AI for learning assistance - An empirical study based on a survey of undergraduates in 20 national universities. *Journal of East China Normal University (Educational Sciences)*, 44(1), 65–79.
- [6] Hou, H. X., & Wang, D. (2025). Risks and avoidance pathways for instructional innovation risks of teachers in the era of generative artificial intelligence. *China Educational Technology*, (3), 20–26.
- [7] Bao, W., Sun, X. Z., & Wu, J. Q. (2025). Deconstructing the constraining factors for enterprise deep participation in industry-education integrated talent cultivation - A mixed-methods study based on AI large language models. *China Higher Education Research*, (7), 8–16.
- [8] Zhang, X. J., Song, Y., & Chen, S. Z. (2025). Analysis of the current situation and challenge review of AIGC-empowered vocational education. *Research and Exploration in Laboratory*, 44(11), 154–158, 190.
- [9] Ministry of Education, National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Science and Technology, & National Data Bureau. (2026, April 2). Notice on issuing the "Action Plan for Artificial Intelligence + Education". http://www.moe.gov.cn/srcsite/A16/s3342/202604/t20260410_1433240.html
- [10] Shi, W. P., & Lin, J. Q. (2025). Basic logic, real challenges, and reform strategies for data governance in higher vocational colleges. *Modern Education Management*, (5), 81–90.
- [11] Chang, J. F. (2026). Logic, risks, and responses of artificial intelligence embedding in social governance - An analysis based on literature review. *Journal of Northwest Minzu University (Philosophy and Social Sciences)*, (2), 76–83.
- [12] Shi, W. P., & Lin, J. Q. (2025). Basic logic, real challenges, and reform strategies for data governance in higher vocational colleges. *Modern Education Management*, (5), 81–90.
- [13] Li, X. T. (2026). Education assessment paradoxes in the intelligent era: AIGC application crisis and assessment paradigm reconstruction. *Distance Education in China*, 46(3), 141–158.
- [14] He, R. L., & Shen, B. (2026). Logical construction and realization pathways for generative AI empowering government governance capacity transformation. *Reform*, (1), 128–139.
- [15] Yang, W. T., & Li, C. W. (2026). Ethical risks and response measures for generative AI application in the education sector. *Journal of Zhongzhou*, (2), 111–118.
- [16] Zheng, H. J. (2025). Research on ethical risks and trustworthy governance pathways of generative artificial intelligence. *Science and Technology Progress and Policy*, 42(12), 38–48.
- [17] Wang, Y. M., Zhang, T. T., & Mao, C. C. (2025). Application scenarios, risk challenges, and countermeasures for generative artificial intelligence in global vocational education. *China Vocational and Technical Education*, (6), 27–33.
- [18] Yuan, P. L., & Song, X. (2025). The hollow idol: A critical reflection on generative AI's educational applications. *Tsinghua Journal of Education*, 46(4), 19–27.
- [19] Wang, F. C., Tang, X. Y., & Yu, S. Q. (2025). Cognitive outsourcing based on generative artificial intelligence: Interactive behavior patterns and cognitive structure characteristics analysis. *Acta Psychologica Sinica*, 57(6), 967–986.

- [20] School of Education, Tsinghua University, & Education Management Information Center of the Ministry of Education. (2026, January 20). Development report on artificial intelligence applications in vocational education (2024–2025). <http://47.92.87.222:2021/evaluate/infoSingleArticle.do?articleId=1384886&columnId=666133>
- [21] Wang, D. (2022). Research on teachers' intelligent educational literacy under the vision of artificial intelligence: Connotation, challenges, and cultivation strategies. *Journal of Chinese Education*, (3), 91–96.