

Research on Cultivating the Industrial Ecosystem and Mechanism of Industry-Education Integration for AI Plus Lifelong Learning

Peiying Fan ¹, Yang Qiu ^{2, *}, Xiaowei He ¹, Guoping Liao ¹

¹ Shanghai Jianqiao University, Shanghai, 201315, China

² Shanghai Technical College of Electronic Information, Shanghai, 201411, China

* Corresponding author: Yang Qiu

Abstract: Against the backdrop of educational digitalization and the development of new quality productive forces, the in-depth empowerment of lifelong learning by artificial intelligence (AI) has become a core starting point for building a learning society. Nevertheless, the domestic "AI + Lifelong Learning" sector is currently plagued by practical shortcomings including fragmented industrial ecosystems, superficial industry-education integration, and mismatched supply and demand in services for diverse groups. Existing studies fail to deliver an integrated theoretical framework and tiered implementation mechanisms. This study aims to clarify the internal coupling logic between industrial ecosystem cultivation and industry-education integration, and establish a quantifiable and implementable collaborative development system. Supported by industrial ecology, lifelong education theory, the Triple Helix model of collaborative innovation, and the Technology Acceptance Model (TAM), this paper identifies four core dilemmas: isolated industrial participants, homogeneous technologies, shortages of interdisciplinary talents, and the absence of adaptive supporting mechanisms. A four-dimensional path for industrial ecosystem cultivation is constructed, namely "participant collaboration—capacity upgrading—demand matching—environmental optimization". Three differentiated integration mechanisms are designed for senior citizens, working professionals and special groups respectively: university-enterprise-community linkage, enterprise-driven and university-supported cooperation, and public welfare-enabled industry-education synergy. Two sets of quantitative evaluation indicators are also formulated covering ecosystem maturity and industry-education performance. The integrated theoretical model and practical framework developed in this research can serve as a decision-making reference for governments to optimize industrial policies, enterprises to launch intelligent products, and universities to advance reforms in digital-intelligent talent cultivation, thereby facilitating the construction of a lifelong learning system.

Keywords: Artificial Intelligence; Industry-Education Integration; Industrial Ecosystem; Educational Digitalization; Lifelong Education.

1. Introduction

The Decision of the Central Committee of the Communist Party of China on Further Deepening Reform Comprehensively to Advance Chinese-style Modernization adopted at the Third Plenary Session of the 20th Central Committee of the Communist Party of China clearly puts forward promoting educational digitalization and empowering the construction of a learning-oriented society, elevating AI-empowered lifelong education to a national strategy. [1] The Outline for Building a Powerful Country in Education (2024-2035) further proposes opening up new tracks for lifelong learning relying on digital technologies and promoting the shift of lifelong education from scale expansion to quality improvement. [2] Driven by new-quality productive forces, the industrial structure keeps iterating, and demands such as updating workplace skills, improving national digital literacy, promoting digital inclusion for the elderly, and realizing educational equity for special groups are expanding simultaneously. The drawbacks of traditional lifelong education, including single resources, fixed scenarios and insufficient personalized supply, have become increasingly prominent.

Artificial intelligence reconstructs the modes of supply, learning, certification and governance for lifelong learning through technologies such as user profiling, adaptive learning

and multimodal interaction. However, the domestic "AI + Lifelong Learning" industry is still in its initial development stage: market entities are loosely linked, technical and product homogenization is severe, and unified industrial standards are absent. Industry-university cooperation remains superficial, limited to practical training and short-term curriculum co-construction. The talent training system in universities lags behind the technological iteration of the AI industry; enterprise R&D lacks scientific research and talent support from colleges and universities; intelligent learning services for different groups are poorly adapted. Against such a background, systematic research on the industrial ecosystem cultivation path and tiered industry-education integration mechanism of "AI + Lifelong Learning" bears important theoretical and practical value.

1.1. Theoretical Value and Practical Significance

This study breaks the research limitation of educational technology that has long focused on K12 and full-time higher education, and expands the theoretical application boundary of AI-empowered education. It introduces industrial ecology and the Triple Helix collaborative innovation theory into the interdisciplinary research field of lifelong education, establishes an integrated analytical framework of "technology empowerment-industrial collaboration-educational support",

reveals the coupling mechanism of two-way empowerment between industrial ecosystem and industry-education integration, and fills the gap in systematic theoretical construction in this field. Meanwhile, it constructs a two-dimensional quantitative evaluation indicator system, making up for the defect that existing researches focus on qualitative description and lack standardized measurement tools, and providing paradigm support for subsequent relevant empirical researches.

This paper puts forward tiered solutions targeting pain points such as industrial fragmentation and industry-education supply-demand mismatch. It provides empirical basis for governments to introduce targeted industrial support policies and unify industrial service standards; offers action guidelines for AI-education enterprises to conduct R&D in segmented tracks and launch age-friendly and barrier-free products; delivers implementable paths for universities to reconstruct the curriculum systems of artificial intelligence, educational technology and elderly service majors and carry out project-based dual teaching. Differentiated industry-education models can improve the precision of lifelong learning services for the elderly, working professionals and special groups, narrow the digital divide, and contribute to the construction of an inclusive learning-oriented society.

1.2. Review of Domestic and Overseas Research Status

(1) Domestic Research Status

Domestic academic circles have accumulated certain research achievements on AI-empowered lifelong learning and digitalized industry-education integration, yet the overall research is fragmented and insufficient in integration. At the macro policy and ecological theory level, some scholars have analyzed the evolutionary logic of the AI + lifelong learning ecosystem under human-AI collaboration, and pointed out structural defects such as isolated industrial resources and insufficient subject linkage, without connecting industrial ecosystem with industry-education integration.[3] Some have sorted out the three-stage evolution of intelligent lifelong education from the perspective of public governance without designing two-way university-enterprise collaboration mechanisms. From the perspective of new-quality productive forces, some scholars propose that the pedagogical system should transform toward lifelong education, which has not been implemented to the practical level of AI industry cultivation.[4] Some have constructed the industry-education integration ecosystem in universities, whose research objects are only full-time on-campus students rather than lifelong learners across the whole life cycle.[5]

In the field of technical empirical research, some scholars have verified the differences in generative AI acceptance among different groups based on tens of thousands of national questionnaires, providing TAM-model-based empirical support for hierarchical adaptation, without extending to the institutional design of industrial collaboration. [6]Existing industry-education integration researches mostly focus on full-time talent training in vocational colleges, analyze the driving logic of AI reconstructing industry-education integration, but fail to design differentiated cooperation modes for the elderly, workplace population and special groups.[7] On the whole, existing results separate industrial development and educational collaboration, lacking an

integrated analytical framework covering learners of all ages, which forms the core innovation space of this research.[8]

(2) Overseas Research Status

Researches on AI-driven lifelong learning and industry-education collaboration in Europe, America, Japan and South Korea started earlier, forming two main lines of refined technical implementation and multi-helix ecological collaboration. [9]Relying on the U.S. National AI Institute for Adult Learning and Online Education, some scholars put forward the learning engineering theory for large-scale implementation of intelligent lifelong learning, focusing on standardized technical procedures, which cannot adapt to local problems in developing countries such as digital divide and uneven resource allocation. [11]Lee et al. verified the value of university-enterprise collaboration on AI-skilled talent cultivation based on the German dual-system, whose research scope is limited to vocational education for working-age population without expanding to continuing education for middle-aged and elderly people.[12]

In terms of large-model technology research, some scholars constructed the technical roadmap of LLM-based lifelong learning agents to realize dynamic learner profiling and adaptive resource push, lacking institutional design for multi-party collaboration among government, universities, enterprises and communities. [13]Kim et al. optimized the AI metacognitive architecture for diverse learners, merely focusing on technical iteration rather than the construction of industrial symbiosis ecosystem. [14] As a mainstream international analytical tool, the Triple Helix model in overseas researches is built on the mature industrial foundation of developed countries, which cannot be directly adapted to China's national conditions such as weak innovation of small- and medium-sized enterprises and unbalanced public services for lifelong education. [15]

(3) Summary of Research Gaps

Synthesizing domestic and foreign literature, there exist three core research gaps. First, theoretical gap: no integrated theoretical model of industrial ecosystem and industry-education integration adapted to the "AI + Lifelong Learning" scenario has been constructed with insufficient multidisciplinary integration. Second, perspective gap: existing researches separate the internal relations among technology application, industrial development and industry-education collaboration, lacking holistic and systematic analysis. Third, practical gap: long-term differentiated industry-education integration mechanisms for diverse lifelong learning groups are absent, and the cultivation path of industrial ecosystem is poorly operable.

2. Core Concepts and Theoretical Basis

2.1. Definition of Core Concepts

AI + Lifelong Learning: A new intelligent lifelong-learning paradigm supported by underlying technologies including artificial intelligence, big data and cloud computing, breaking the barriers of time-space and resources for social groups of all ages and occupations. Centered on learners' demands, it relies on intelligent algorithms to realize accurate resource push, dynamic monitoring of learning processes and intelligent evaluation of learning effects. It covers multiple scenarios including workplace skill upgrading, elderly digital literacy cultivation, barrier-free education for special groups and improvement of national comprehensive literacy, serving as the core form of deep integration between educational

digitalization and lifelong learning system.

Industrial Ecosystem of AI + Lifelong Learning: A dynamically-evolving multi-agent symbiotic industrial system formed following industrial ecology logic. It consists of three layers: core subjects (AI-technology enterprises, lifelong-education service institutions and various learners), supporting subjects (governments, university research institutes, industrial associations and community service centers), and environmental elements (policies and regulations, industrial standards, talent systems, market culture and data-security norms). All subjects form a closed-loop collaborative system through joint talent cultivation, co-research of technologies, resource sharing as well as benefit-risk sharing.

Hierarchical Industry-Education Integration Mechanism: A long-term collaborative system adapting to diversified group demands of "AI + Lifelong Learning". Different from the single university-enterprise cooperation mode in traditional vocational education, it includes five sub-mechanisms: talent training, technology R&D, resource sharing, service implementation, and benefit-risk distribution. Differentiated cooperation modes are designed for elderly, workplace and special learning groups to achieve precise matching among industrial demands, scientific-research innovation and lifelong-education services.

2.2. Core Theoretical Basis

Industrial Ecology: It interprets the laws of subject symbiosis, resource circulation and ecological evolution within industrial systems. It is adopted to analyze roles and value circulation paths of various subjects in the "AI + Lifelong Learning" industry, diagnose root causes of industrial fragmentation, and provide underlying logic for building multi-agent collaborative ecosystem cultivation paths.

Lifelong Education Theory: It emphasizes the universality, whole-process and universality of education, requiring education to cover individuals' complete life cycle. It provides value orientation for distinguishing learning demands of different groups and designing inclusive hierarchical services in this research.

Triple Helix Collaborative Innovation Theory: It focuses on resource integration and complementary advantages among government, university and industry to break subject barriers. It supports the construction of four-party collaborative system of government university enterprise community and improves whole chain collaboration rules for talent, technology and services.

Technology Acceptance Model (TAM): It explains learners' willingness to adopt AI-enabled intelligent learning products and usage barriers, serving as an empirical analytical tool for differentiated intelligent product adaptation and optimization of industry-education integration services in this research.

3. Real-world Dilemmas of "AI + Lifelong Learning" Industrial Ecosystem and Industry-Education Integration

3.1. Development Status of Industrial Ecosystem

Driven by national educational-digitalization policies, the scale of domestic "AI + Lifelong Learning" industry keeps

expanding with gradually-formed segmented tracks. A number of science-and-technology enterprises have deployed products for intelligent vocational training, age-friendly learning for the elderly and barrier-free education. Provinces and cities have built regional digital public platforms for lifelong learning. Universities, communities and private training institutions participate in the implementation of intelligent-learning services, initially forming a pattern with multi-subject participation. Iterative technologies such as big data, generative AI and virtual simulation provide technical support for personalized supply of lifelong learning. Nevertheless, the industry as a whole has not entered the stage of mature collaborative development.

3.2. Development Status of Industry-Education Integration

Current university-enterprise cooperation in China remains superficial. Universities and AI enterprises co-build short-term practical-training bases and jointly develop basic courses. Pilot regions in the Yangtze River Delta and Pearl River Delta have explored the "university enterprise community" cooperation mode for digital classrooms for the elderly. Enterprises carry out short-term skill training for their employees relying on university teachers. Overall cooperation lacks long-term institutional constraints. The whole-chain collaborative system for talent training, key-technology research and grassroots-service implementation has not been established, leading to low efficiency of industry-education collaboration.

3.3. Four Core Development Dilemmas

First, fragmented industrial ecosystem with multi-subject collaboration obstacles. Government, university, enterprise and community have blurred power-responsibility boundaries, lacking regular resource-sharing platforms. Enterprises suffer from homogeneous competition with repeated construction of upstream-and-downstream industrial-chain resources. University scientific-research achievements are disconnected from market scenarios with low technology-transformation efficiency. Grassroots community services are disconnected from front-end technology R&D and talent training. The absence of unified national standards for technology, services and evaluation restricts standardized industrial development.

Second, superficial industry-education integration featuring two-way supply-demand mismatch of talents and technologies. In terms of talent cultivation, university curricula update lags behind AI technological iteration; teaching focuses on theories with insufficient practical training in lifelong-learning scenarios, resulting in a shortage of compound digital-intelligent educators. In terms of technology R&D, university-enterprise joint research is limited to basic projects without tackling core technologies in segmented scenarios such as age-friendliness and barrier-free access. In terms of resource circulation, university teachers and scientific-research data can hardly empower enterprises, while real-world enterprise projects and scenario resources cannot feed back classroom teaching, forming a supply-demand mismatch of "industry in want of talents and education in want of scenarios".

Third, homogenized intelligent services with poor adaptability for diverse groups. Mainstream AI learning products in the market adopt general-purpose design without hierarchical customized services. For workplace groups, there lacks a dynamic iterative training system for post-specific

skills. Products for the elderly are complex to operate with insufficient age-friendly transformation, failing to bridge the digital divide. Barrier-free intelligent-learning products for special groups are in short supply without supporting public-welfare mechanisms, making it difficult to realize the inclusiveness of lifelong education.

Fourth, absence of long-term guarantee system leading to insufficient endogenous driving force for industrial development. Institutionally, there are no special supporting policies for "AI + Lifelong Learning" or incentive-restrictive norms for industry-education integration. In terms of talents, there exists a huge gap for compound teachers and R&D personnel equipped with both AI technologies and lifelong-education literacy. In the market, small- and medium-sized enterprises are faced with high R&D costs and narrow financing channels, resulting in insufficient innovation vitality. Supporting mechanisms for intellectual property rights, achievement transformation and learning-outcome certification are imperfect, which cannot sustain the long-term coordinated development of industry and education.

4. Four-dimensional Cultivation Path for the "AI + Lifelong Learning" Industrial Ecosystem

Targeting pain points such as industrial fragmentation and supply-demand mismatch, this paper constructs a four-dimensional cultivation path of "participant collaboration capacity upgrading demand matching environmental optimization", promoting the industry to evolve from decentralized development toward a closed-loop symbiotic ecosystem.

(1) Reconstruct Multi-subject Collaborative System to Remove Ecosystem Linkage Barriers

Clarify functional positioning of four types of subjects: governments undertake top-level policy design, formulation of industrial standards, market supervision and coordination of public resources; universities and research institutes focus on talent cultivation, tackling key technologies in segmented scenarios and constructing theoretical systems; as market players, AI enterprises delve into segmented tracks to realize R&D and commercial implementation of intelligent products; communities are responsible for promoting grassroots learning services, collecting user feedback and implementing offline teaching. Build regular cross-subject collaborative platforms, establish mechanisms for project co-construction, resource sharing, benefit distribution and risk-sharing, and form a collaborative pattern of "government guidance, university empowerment, enterprise leadership and community implementation".

(2) Strengthen Core Industrial Capabilities and Stimulate Technological Innovation Vitality

In the dimension of technological innovation, support universities and enterprises to co-build joint laboratories to carry out joint research targeting segmented scenarios such as age-friendly voice interaction, barrier-free learning adaptation and dynamic workplace-skill evaluation, so as to cope with product homogenization. In the dimension of resource integration, construct a national integrated digital-resource-sharing platform for lifelong learning to break information silos by connecting university curricula, enterprise technical data and community offline-service resources. In the dimension of market services, guide

enterprises to cultivate vertical segmented tracks and optimize product functions for different groups. Meanwhile, improve investment-and-financing supporting policies for small- and medium-sized enterprises to reduce R&D costs and release industrial innovation momentum.

(3) Match Demands of Diverse Groups Hierarchically and Improve Inclusive Service Efficiency of the Ecosystem

For workplace groups: build a dynamically-updated fragmented vocational-skill training system adopting AI post-profiling technology, and provide progressive customized courses matching iterative post demands. For elderly groups: comprehensively promote age-friendly transformation of intelligent products, jointly launch AI digital classrooms with communities and support offline volunteer-assistance mechanisms. For special groups: establish a public-welfare empowerment system. Cooperate with universities and enterprises to develop low-cost barrier-free learning tools and provide free intelligent learning assistance services to narrow the digital divide in lifelong learning.

(4) Optimize Industrial Institutional Environment and Lay a Solid Foundation for Long-term Development

Policy environment: introduce special industrial preferential tax policies, subsidies for industry education integration projects and incentive policies for scientific research achievement transformation. Talent environment: drive universities to optimize talent-training schemes for majors including educational technology, artificial intelligence and elderly services, and improve the system for dual qualified teachers to practice in enterprises. Evaluation environment: construct a quantitative evaluation system for industrial ecosystem maturity and carry out dynamic assessment from four dimensions: subject collaboration degree, technological-innovation degree, group adaptation degree and service inclusiveness degree. Supervision environment: perfect norms for data security protection, intellectual property right protection and industrial competition supervision to guard against risks of AI ethics and market disorder.

5. Innovative Differentiated Hierarchical Industry Education Integration Mechanisms

In view of demand differences among three types of lifelong-learning groups, three implementable long-term integration mechanisms are constructed together with unified supporting sub-mechanisms to solve the "disconnection between industry and education" problem.

5.1. Age-friendly Learning for the Elderly: University enterprise community Tripartite Linkage Mechanism

Universities carry out demand surveys on elderly learning, develop age-friendly curricula and cultivate compound teachers relying on educational-technology and elderly-service majors. AI enterprises cooperate with universities to develop lightweight intelligent-learning platforms with low-operation thresholds for the elderly. Communities undertake offline public-welfare teaching, product trial and demand feedback relying on party-mass service centers and elderly learning halls. The three parties hold quarterly coordination meetings to share curriculum resources, user data and service outcomes for continuous

iteration of age-friendly learning services, realizing grassroots implementation of digital education for the elderly.

5.2. Skill Upgrading for Working Professionals: Enterprise driven and University-supported Integration Mechanism

Centered on iterative skill demands of industrial posts, leading AI enterprises output talent-competency standards, real-world project cases and technological-iteration directions to universities. Universities dynamically reconstruct modular curricula, implement the dual-tutor system of "enterprise tutors + on-campus teachers", project-based practical training and order-oriented talent cultivation. Universities and enterprises jointly build R&D centers for workplace AI skills, co-develop intelligent post-evaluation and fragmented-training products. It simultaneously realizes targeted delivery of compound talents and scenario verification of industrial technologies, precisely matching lifelong career-development demands of workplace population.

5.3. Inclusive Learning for Special Groups: Public welfare empowered plus Industry education Synergy Mechanism

Governments take the lead in building a public-welfare service platform for lifelong learning of special groups with special supporting funds. Universities organize volunteer teams to develop customized barrier-free curricula and provide guidance for public-welfare teaching. AI enterprises fulfill social responsibilities to develop low-cost barrier-free intelligent-learning systems and open free learning access ports. Multi-parties collaborate to carry out online learning assistance and targeted offline support, make up for the shortage of lifelong-learning resources for special groups and advance educational equity.

5.4. Four Supporting Sub-mechanisms

(1) Collaborative Talent-cultivation Mechanism: Improve modes including on-the-job practical training in enterprises, mutual appointment of dual-qualified teachers, order-oriented classes and co-construction of industrial colleges to realize precise docking between talent supply and industrial demands.

(2) Collaborative Technology-R&D Mechanism: Establish systems for university-enterprise joint research, shared intellectual-property rights and benefit distribution of achievements to enhance the transformation rate of technological implementation.

(3) Resource-sharing and Circulation Mechanism: Realize interconnection of curricula, teachers, experimental scenarios and user data for cyclic reuse of resources.

(4) Benefit-risk Sharing Mechanism: Clarify rights-obligations of all parties, benefit distribution and R&D risk-sharing rules; perfect systems for dispute mediation and intellectual-property-right protection to guarantee long-term stable operation of integration mechanisms.

6. Conclusion

Against the backdrop of educational digitalization and new-quality productive forces, AI-empowered lifelong learning is critical for building China's learning-oriented society. Based on industrial ecology, lifelong education theory, the Triple Helix model and the Technology Acceptance Model,

this paper identifies four major challenges: fragmented industrial ecosystem, superficial industry-education integration, homogenized intelligent learning services for diverse learner groups, and insufficient long-term supporting systems.

This study establishes a four-dimensional cultivation path of "participant collaboration-capacity upgrading-demand matching-environmental optimization" for the "AI + Lifelong Learning" industrial ecosystem. Targeting the elderly, working professionals and special groups, three differentiated industry-education integration mechanisms together with supporting sub-mechanisms for talent cultivation, joint R&D, resource sharing and benefit-risk sharing are proposed to ease the industry-education disconnect. The findings can offer references for governmental policy-making, enterprise product development and university talent training reform.

Limited by samples mainly from the Yangtze River Delta, the quantitative evaluation indicators in this paper remain theoretically constructed without adequate empirical validation. Future research will expand regional samples, integrate large-model lifelong-learning agent techniques, conduct long-term pilot tests to revise evaluation systems, and further explore AI ethics and data governance, so as to advance the high-quality development of lifelong learning in China.

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