Theoretical Research on Personalized Empowerment Intelligent Agent for Teachers' AI Literacy Based on Competency Diagnosis

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Abstract

Against the backdrop of the continuous deepening of educational digital reform, national and Zhejiang provincial authorities have successively issued a series of policy documents on teachers' artificial intelligence (AI) literacy, establishing clear standards for competency development among regional teachers. However, the current cultivation of teachers' AI literacy generally faces practical dilemmas including "difficult policy standard implementation, homogenized training, and disconnection between competency diagnosis and targeted empowerment". Existing literacy frameworks mostly focus on the formulation of macroscopic competency standards while lacking refined diagnostic indicators tailored to frontline teaching scenarios. Unified training models fail to match the personalized competency shortcomings of teachers across different educational stages and teaching seniority, and the one-size-fits-all curriculum system cannot support precise competency improvement. Furthermore, the separation between competency diagnosis and cultivation empowerment means that evaluation results are only used for current situation investigation, rather than mapping targeted improvement paths. Based on constructivist learning theory, technology-enhanced learning theory, and adaptive learning system theory, this study adopts literature analysis, policy analysis, Delphi method, and systematic design methods. Combined with the developmental characteristics of primary, secondary, and university teachers in Zhejiang Province and relying on internationally authoritative and mature evaluation tools, it constructs a localized three-dimensional (3D) diagnostic system for teachers' AI literacy. This study further designs a two-stage "recognition-response" personalized empowerment intelligent agent and builds a full-cycle closed-loop improvement system covering "evaluation and diagnosis, intelligent empowerment, feedback and iteration". This research fills the theoretical gap of diagnosis-oriented localized research on teachers' AI literacy, innovates the integrated empowerment paradigm of "promoting learning through evaluation and verifying learning through practice", and provides theoretical support and tool design references for the precise cultivation of teachers' AI literacy and the implementation of educational digital transformation policies in Zhejiang Province.

Keywords

Teachers' artificial intelligence literacy, Competency diagnosis, Educational intelligent agent, Personalized empowerment, Educational digitalization

Introduction

Research background

(1) Policy driving force: Teachers' AI literacy as a core task of educational modernization

China Education Modernization 2035 incorporates the construction of teachers' digital and AI competencies into the core goals of educational development [1]. The 2024 National Education Conference emphasizes that educational digitalization should empower the reform of education and teaching paradigms, and regards intelligent technology application capability as a mandatory indicator for teachers' professional development [2]. In 2024, UNESCO released the Teacher Artificial Intelligence Competency Framework. This document defines five core developmental dimensions such as AI cognition, teaching integration and ethical norms. Meanwhile, it puts forward a

universal global principle: technology empowers people-oriented education, and ethics sets the limits for its application [3]. As a national pioneer in educational digital reform, Zhejiang Province issued two official policy documents in 2025. They are the Zhejiang Provincial Primary and Secondary School Teachers' Artificial Intelligence Literacy Framework (Trial) and the Zhejiang Provincial University Teachers' Artificial Intelligence Literacy Framework (Trial). It constructs a hierarchical and categorized provincial standard system covering all educational stages adapted to local educational scenarios.

Meanwhile, the province released the Zhejiang Provincial Action Plan for AI Empowering Innovation and Quality Improvement of University Education and Teaching (2025-2027), which clarifies the transformation of literacy standards into implementable and testable cultivation paths and explores the "Zhejiang Experience" for national teachers' AI literacy improvement. From national top-level design to regional implementation rules, the policy logic consistently highlights "standard guidance, precise empowerment, and closed-loop implementation". Nevertheless, at the practical level, there is a lack of mature theoretical support and tool design for transforming macroscopic policy indicators into specific measurable competency dimensions for frontline teachers.

(2) Practical dilemmas: Structural supply-demand contradictions in teachers' AI literacy cultivation

Nationwide, teachers' AI literacy is generally characterized by "intermediate overall level, dimensional imbalance, and group differentiation". The 2026 Report on Chinese Teachers' Generative Artificial Intelligence Application released by the Center for Educational Technology and Resource Development of the Ministry of Education shows that over 80% of Chinese teachers recognize the teaching value of AI technology. Their practical applications are mostly limited to shallow scenarios such as resource retrieval and courseware production. More than 60% of teachers have never adopted AI technology for learning situation analysis or personalized teaching. The literacy gap continues to widen between urban and rural teachers, as well as teachers at different educational stages. Rural teachers are deficient in basic technology application capabilities, while urban teachers lack targeted guidance for high-level teaching integration. Teachers in eastern China demonstrate significantly higher demand for AI teaching integration than those in central and western regions. In Zhejiang Province, although provincial-level teacher intelligent training platforms and "teaching and research brain" systems have been built to support regular teaching and research activities, the existing training system still has three unavoidable defects [4,5].

First, literacy frameworks prioritize standards over diagnosis. Official frameworks only define three major dimensions including basic literacy, ethical norms, and applied literacy, without refined diagnostic indicators adapted to teaching scenarios, making it impossible for training organizers to accurately identify teachers' real competency shortcomings. Second, the training model is homogenized. Curriculum design focuses on technical tool explanation without hierarchical content differentiated by educational stage, discipline, and teaching seniority, which is seriously mismatched with teachers' actual demand for lightweight, scenario-based, and implementable learning. Third, diagnosis is disconnected from empowerment. Although some schools have introduced third-party literacy evaluation tools, evaluation results are only used for overall status statistics rather than matching targeted improvement schemes, forming a dead loop of "evaluation without intervention".

(3) Technological opportunity: Intelligent agents as a feasible path for precise training implementation

With the core technical characteristics of data-driven decision-making, personalized recommendation, and dynamic iteration, adaptive educational intelligent agents are critical tools for solving homogenized training and realizing precise teacher development. Different from traditional passive AI tools that only execute single instructions such as courseware generation and homework correction, agentic AI is an independent technical carrier with the capabilities of active perception, autonomous decision-making, and iterative optimization. It can independently collect and analyze teachers' evaluation data, learning behavior data, and teaching scenario data to accurately identify competency deficiencies. Supported by its built-in inference engine, it develops personalized training schemes adapted to

teaching scenarios. Strategies can be dynamically adjusted based on real-time learning feedback, so as to deliver personalized and precise empowerment for every teacher [6]. Domestic educational intelligent agents have evolved from theoretical exploration to scenario-based implementation.

In 2026, iFLYTEK launched the "Starlight" educational intelligent agent, realizing automatic integration of learning situation data, differentiated assignment generation, and home-school collaborative report output for teachers. Tomorrow Advancing Life (TAL) Education Group developed the "NineClaw" intelligent agent, which is embedded in daily office scenarios to help teachers complete teaching plan generation and teaching resource optimization without additional learning burdens. Internationally, "Brisk Teaching", a mainstream American teaching AI tool, adopts a lightweight embedding logic to support one-click teaching plan generation, differentiated assignment design, and originality detection, improving teachers' technology acceptance through workflow-oriented design [7]. The maturity of current technological practices verifies that intelligent agents driven by standardized competency diagnosis data can bridge the whole link of evaluation, analysis, empowerment, and iteration. It can effectively make up for the defects of traditional training systems and provide solid technical support for the improvement of teachers' AI literacy in Zhejiang Province.

Research problems

In view of the gap between policy orientation and practical dilemmas, combined with the application potential of intelligent agent technology, this study focuses on three core academic problems to construct theoretical and tool support systems:

(1) Model construction: How to construct a hierarchical and implementable three-dimensional theoretical model of teachers' AI literacy centered on individual deficiency diagnosis? The construction shall be based on the teaching scenarios of primary, secondary, and university education in Zhejiang Province, national and provincial policy standards, and local teachers' actual literacy status with the support of authoritative evaluation frameworks.

(2) Tool design: How to design a two-stage "recognition-response" educational intelligent agent architecture driven by standardized authoritative scale diagnosis data? It transforms evaluation data into personalized training paths adapted to teachers' daily teaching scenarios, and realizes "learning promotion through evaluation and deficiency compensation through learning".

(3) Mechanism operation: How to build a full-cycle closed-loop system of "evaluation diagnosis, intelligent empowerment, re-test feedback, and model iteration"? It deeply integrates the technical logic of intelligent agents with teachers' professional development logic, and fundamentally solves the traditional dilemmas of diagnosis-empowerment disconnection and training homogenization.

Research significance

(1) Theoretical significance

First, this study improves the localized diagnosis-oriented theoretical system of teachers' AI literacy. Most existing teacher AI literacy frameworks focus on macroscopic standard formulation and unified technical operation requirements, with few designs centered on individual deficiency identification. Strictly aligning with Zhejiang provincial official literacy standards and relying on international authoritative evaluation frameworks, this study decomposes three core dimensions including basic literacy, applied literacy, and ethical norms from practical teaching scenarios. It constructs a hierarchical three-dimensional literacy diagnosis model suitable for all educational stages. It fills the local theoretical gap of "abundant standard-oriented frameworks but insufficient diagnosis-oriented models". It transforms macroscopic policy competency requirements into observable, evaluable, and scenario-based specific indicators, enriches the theoretical connotation of regional teachers' AI literacy research, and provides a localized theoretical paradigm for similar regional studies in China.

Second, this study innovates the integrated research paradigm of diagnosis and empowerment. Current domestic research on intelligent agent empowerment for teacher development mostly focuses on technical efficiency improvement, taking resource pushing quantity and task duration as core evaluation indicators. It ignores the precondition of standardized authoritative diagnosis for personalized resource matching, resulting in long-term disconnection between diagnosis and

empowerment. Driven by mature scale diagnosis data, this study bridges the complete technical chain of deficiency identification, personalized resource matching, training implementation, and data re-test, constructing a closed-loop empowerment system of "evaluation - empowerment - feedback - iteration". It deeply integrates the technical logic of intelligent agents with the professional development logic of teachers, theoretically clarifying the core issues of diagnosis-empowerment connection, precise empowerment, and sustainable development, and enriching the theoretical perspective of adaptive teacher training.

Third, this study refines the academic logic of hierarchical empowerment. Different from the unified standards and generalized paths adopted in traditional research, this study designs hierarchical diagnostic indicators and adaptive intelligent agent empowerment paths based on the literacy differences of teachers at different educational stages, teaching seniority, and disciplines. It transforms the abstract propositions of educational equity and precise education theories into implementable technical architectures and operational rules, providing refined academic references for research on precise cultivation of teachers' digital literacy.

(2) Practical significance

First, it supports the development of regional precise training tools. This study adopts the internationally authoritative and rigorously validated teacher artificial intelligence competence self-efficacy (TAICS) scale, which is adapted to the evaluation scenarios of teachers at all educational stages in China. It provides standardized and scientific evaluation basis for the Zhejiang Provincial Center for Educational Technology to develop provincial-level teacher AI literacy training tools. Educational administrative departments can accurately grasp the distribution status and subdivided competency shortcomings of regional teachers' literacy through scale data, providing real data support for regional training curriculum planning and resource allocation, and avoiding blindness of administrative decision-making.

Second, it provides an implementable intelligent agent design scheme. The two-stage "recognition-response" intelligent agent architecture constructed in this study adopts the design concepts of lightweight deployment, scenario adaptation, and low learning cost. It provides mature technical references for schools and regional educational departments in Zhejiang Province to build teacher intelligent training platforms. Schools can develop scenario-adaptive training systems based on this architecture, reducing the system's R&D costs while realizing personalized precise empowerment for teachers.

Third, it promotes policy implementation and balanced educational development. The closed-loop support system effectively solves the problems of mismatched training content and scenarios and low resource accuracy in traditional training. It transforms unified provincial literacy standards into personalized improvement paths adapted to teachers' differentiated teaching scenarios, focusing on matching lightweight and implementable training resources for vulnerable groups such as rural teachers and novice teachers with weak basic digital literacy. It accurately narrows the literacy gap between teachers in different regions, educational stages, and groups, and promotes the balanced and high-quality development of the overall teacher team in Zhejiang Province.

Research ideas and methods

(1) Research ideas

Following the academic logic of "problem sorting, theoretical tracing, model construction, system design, and application planning", this study is carried out in five core stages:

a) Problem sorting

This stage systematically sorts out national and provincial policies on teachers' AI literacy to clarify policy orientation. It comprehensively reviews domestic and foreign literature on teachers' AI literacy, competency diagnosis, and educational intelligent agents. It summarizes research deficiencies and practical pain points and defines the core research direction and key problems.

b) Theoretical tracing

This stage takes constructivist learning theory, technology-enhanced learning theory, and adaptive learning system theory as the underlying support, analyzes the core propositions of the three theories, and clarifies their adaptive logic with literacy diagnosis and intelligent agent empowerment. It defines theoretical benchmarks and design principles based on the design

basis of local provincial literacy frameworks and the dimensional logic of international authoritative evaluation frameworks.

c) Model construction

Based on Zhejiang provincial official literacy frameworks, anchored by the core dimensions of the mature TAICS scale, combined with domestic empirical research conclusions and local teaching scenarios, this study constructs a localized three-dimensional teacher AI literacy diagnosis model. It adopts expert Delphi method to correct model adaptability to meet the developmental needs of teachers at all educational stages in Zhejiang Province.

d) System design

Guided by adaptive learning system theory, this study designs a two-stage "recognition-response" intelligent agent architecture, clarifies the functions and operational logic of core modules, and builds a hierarchical training resource library matching model indicators and scale dimensions. It further constructs a full-cycle closed-loop operational mechanism of "evaluation diagnosis, intelligent empowerment, feedback iteration, and dynamic optimization" to realize deep integration of technical logic and teachers' professional development logic.

e) Application planning

This stage designs a quasi-experimental research scheme, clarifies sample selection rules, variable measurement standards, data collection tools and analysis methods, and plans pilot applications in parts of Zhejiang Province. It adopts authoritative scales for pre-test and post-test data collection to verify model effectiveness and intelligent agent empowerment effects, and iteratively optimizes model indicators and system operational logic based on teachers' practical feedback.

(2) Research methods

a) Literature analysis method: Based on CNKI, Web of Science core collection, and authoritative educational journals, this study systematically retrieves Chinese and English literature on teachers' AI literacy, diagnostic evaluation, and intelligent agent empowerment from 2019 to 2025. It clarifies research hotspots, evolutionary trajectories and technical application status in this field. It summarizes the dimensional configuration and evaluation logic of mainstream literacy frameworks and authoritative scales. It also identifies research gaps to supply theoretical foundation and innovative insights for model construction and intelligent agent development.

b) Policy analysis method: This study interprets national, ministerial, and Zhejiang provincial policy documents related to teachers' AI literacy. It decomposes the three core dimensions and subdivided scenarios of Zhejiang's primary and secondary school and university teacher AI literacy frameworks. It sorts out hierarchical competency requirements and value orientation for teacher development. It deeply adapts macroscopic policy requirements to the dimensional logic of authoritative evaluation scales to ensure high consistency between the constructed model and official standards.

c) Delphi method: An expert group of more than 15 members including educational technology scholars, frontline outstanding teachers, senior researchers in university teacher development centers, and educational administrators is invited for multiple rounds of anonymous reviews. Experts provide revisions on model dimensions, scale adaptability, and intelligent agent architecture based on policy documents, literature reviews, and model design basis. The research indicators and system schemes are finalized after repeated summary, feedback, and adjustment until expert opinions reach academic consistency standards.

d) System design method: Based on adaptive learning system theory, this study adopts a modular design approach to divide the intelligent agent system into three hierarchical levels: learner layer, multi-agent core layer, and resource library layer, clarifying the core functions and collaborative mechanism of each layer. It designs the two-stage operational logic of "recognition-response", connects diagnostic data with personalized training resources, and constructs a closed-loop operational mechanism to realize the deep integration of technical system logic and teachers' professional development logic.

e) Quasi-experimental research method: Pilot applications are carried out in primary, secondary, and university schools in different urban and rural areas of Zhejiang Province. Participants are divided into experimental groups and control groups with matched demographic characteristics. The control group adopts traditional homogenized training, while the experimental

group adopts the intelligent agent closed-loop empowerment system designed in this study. The localized adapted TAICS scale is used for pre-test and post-test data collection. SPSS and SmartPLS are employed for quantitative analysis to verify the empowerment effect. Semi-structured interviews are conducted to collect teachers' practical feedback for system iteration and optimization.

Literature review

Research on connotation and dimension construction of teachers' AI literacy

Domestic research on teachers' AI literacy presents a three-stage evolutionary logic. The conceptual embryonic stage (2017-2020) mainly focused on the technical operation part of teachers' general digital literacy, with AI literacy only as a supplementary content [8]. The framework exploration stage (2021-2023) shifted the research focus from "tool use" to "teaching scenario integration", with independent teacher AI literacy frameworks initially constructed [9]. The connotation reconstruction stage (2024-present) is driven by the rapid popularization of generative AI technology, forming a comprehensive dimension covering technical application, teaching innovation, and ethical norms, with the core logic transforming from tool-oriented use to education value-oriented application [10].

Current mainstream domestic framework designs are based on policies and mature theories. The research team of Southwest University defines teachers' AI literacy across five dimensions: AI cognition and application awareness, technical principles and general skills, teaching application practice, social responsibility, and empowering teachers' professional development. The framework reflects a progressive logic extending from cognition to practice [11]. Vocational education research divides literacy into general AI literacy, AI teaching application literacy, and AI ethical literacy based on Bloom's cognitive classification theory, forming a progressive hierarchy of "understanding AI, applying AI in teaching, and evaluating and innovating AI teaching" [12]. The official Zhejiang provincial framework constructs a trinity structure of basic literacy, applied literacy, and ethical norms adapted to local education. In this framework, basic literacy includes value understanding and technical skills. Applied literacy covers teaching, research, and student management scenarios. Ethical norms involve security, equity, and efficiency, providing clear guidance for local teacher literacy improvement.

In international research, UNESCO's 2024 Teacher Artificial Intelligence Competency Framework takes "people-oriented education" as the core principle. It defines five core dimensions: AI cognition, teaching application, ethical norms, professional development, and critical thinking. It emphasizes the core value of "technology assisting teaching rather than replacing teaching to serve student development" [13]. Tadimalla and Maher define teachers' AI literacy from the perspective of human-technology collaboration as a comprehensive competency to critically evaluate AI technology, collaborate effectively with AI, and take AI as a teaching tool [14]. The European Commission's literacy framework prioritizes pedagogy, focusing on three key priorities: technical understanding, pedagogical application, and ethical and legal awareness [15].

Overall, existing literacy frameworks have two obvious defects. First, there are more universal frameworks and fewer locally adaptive frameworks. International frameworks focus on general competencies without adapting to domestic educational scenarios and policy goals; domestic frameworks are mostly macroscopic national standards lacking refined hierarchical indicators matching Zhejiang's local educational conditions. Second, standard-oriented frameworks are far more prevalent than diagnosis-oriented ones. Most existing frameworks emphasize unified competency standards but rarely decompose indicators from the perspective of individual teacher deficiency identification, lacking quantifiable and scenario-based evaluation support for precise empowerment.

Research on teachers' AI competency diagnosis and evaluation tools

Diagnostic evaluation is the prerequisite for precise empowerment. International academia has developed a set of authoritative and rigorously verified teacher AI literacy evaluation tools with reliable validity. These tools can be directly applied to scenario-based teacher literacy evaluation and provide standardized support for empirical research and practical diagnosis. Among them, the TAICS scale developed and verified in 2024 is one

of the most adaptable and widely recognized authoritative tools in current research. Optimized by Delphi method and verified by large-sample empirical data, the scale has excellent reliability, validity, and measurement invariance [16].

It is suitable for kindergarten through 12th grade (K12) and university teacher evaluation, covering six mature dimensions: AI knowledge cognition, AI pedagogical application, AI teaching evaluation, AI ethical norms, humanistic education practice, and sustainable professional development. Its dimensional system fully covers the mainstream connotation of teachers' AI literacy and is highly consistent with Zhejiang's local literacy framework. A mature research paradigm has been established for the evaluation system of deep learning capabilities under domestic blended learning scenarios. Li et al. constructed a quantitative evaluation and hierarchical improvement path targeting learners' deep learning capabilities and verified that standardized assessment data can be directly linked to personalized learning improvement schemes [17]. This offers practical references for similar educational evaluation implementation in the present study, which leverages diagnostic data from the TAICS scale to enable precise empowerment of intelligent agents and realize a closed loop of "evaluation-improvement".

Other mainstream international authoritative scales include the artificial intelligence pedagogical content knowledge (AIPACK) scale and artificial intelligence literacy (AIL) general literacy scale, focusing on teachers' AI teaching knowledge structure and general AI literacy level respectively [18,19]. Compared with other tools, the TAICS scale has outstanding advantages in universality and scenario adaptability, fitting both international AI education standards and domestic basic and higher education teaching scenarios. Its high matching degree with the three-dimensional diagnosis model of this study avoids the academic defects of self-developed scales such as insufficient reliability and validity.

In contrast, most domestic evaluation tools are self-designed regional questionnaires lacking rigorous academic verification, with insufficient scientificity and universality. Domestic evaluation practices generally have three core problems: decoupled evaluation dimensions from teaching scenarios, lack of hierarchical adaptive design for different educational stages, and separation of diagnosis and empowerment. Most domestic tools are only used for current situation investigation without linkage to personalized improvement schemes. The introduction of the internationally mature TAICS scale can make up for the scientific defects of domestic evaluation tools and provide standardized and data-driven support for precise diagnosis and targeted empowerment in this study.

Research on educational intelligent agents empowering teacher development

Educational intelligent agents are the core technical carrier for teacher precise empowerment, evolving from traditional passive AI to agentic AI with active cognitive capabilities. Traditional passive AI only completes single instruction-based tasks, while agentic AI possesses the full capability chain of autonomous goal setting, action planning, tool invocation, and reflective iteration. It can independently complete the whole process from learning situation analysis to personalized scheme generation to meet teachers' comprehensive developmental needs.

In terms of architectural design, mainstream academic research adopts the Multi-Agent System (MAS) framework, which decomposes complex teacher empowerment tasks into modular subtasks completed by specialized agents to solve the limitations of single-agent systems [20]. Cheng et al. constructed an intelligent support system for university students based on the BP neural network and verified the application value of neural network algorithms in educational user profiling, hierarchical demand identification and personalized service push. It provides a reference for the technical paradigm of the multi-agent "identification-response" hierarchical reasoning algorithm and the construction of teacher competency profiling in this paper [21]. Two typical international mature architectures are widely adopted. First is the framework for agent-based classroom enhancement for teachers (FACET) four-agent modular architecture proposed by Stanford University, which divides empowerment tasks into learner simulation, diagnostic reasoning, resource generation, and effect evaluation modules to adapt to personalized training needs. Second is the hierarchical

LectūraAgents framework developed by the Swiss Federal Institute of Technology in Zurich (ETH Zurich). It adopts top-level overall planning, middle-level execution, and bottom-level implementation collaborative logic to support teachers' sustainable development.

In terms of application scenarios, domestic intelligent agent applications have expanded from single scenarios to full-process coverage, with mature industrial technologies realized in scenario-based implementation. However, current applications still have prominent deficiencies. There is a lack of standardized diagnostic data input, relying only on scenario behavior data for resource pushing without accurate deficiency positioning based on authoritative literacy evaluation. Closed-loop iteration mechanisms are absent, adopting one-way resource pushing without effect re-test and strategy optimization. Hierarchical adaptability is insufficient, failing to meet the differentiated needs of teachers at different competency levels and educational stages.

Research review and research entry point

Existing domestic and foreign research has laid a basic foundation in teacher AI literacy framework construction, diagnostic evaluation tools, and intelligent agent application, but three core research gaps remain.

First, there is a lack of localized diagnosis-adaptive theoretical systems. Existing universal literacy frameworks cannot adapt to the hierarchical scenario characteristics of Zhejiang's local educational stages, and most focus on standard definition rather than deficiency diagnosis and precise empowerment implementation logic.

Second, there is a lack of scientific diagnosis-empowerment integrated tools. Most domestic studies adopt unverified self-designed scales with insufficient standardization, and the widespread diagnosis-empowerment disconnection makes evaluation data unable to link with targeted improvement paths.

Third, there is a lack of full-cycle closed-loop operational mechanisms. Existing intelligent agent applications are limited to one-way empowerment without complete links of evaluation, iteration, and optimization, failing to support teachers' long-term professional development.

Based on the above gaps, this study establishes its core entry point. It relies on the internationally authoritative mature TAICS scale, combining Zhejiang's local policies and teaching scenarios. It optimizes and constructs a localized three-dimensional literacy diagnosis model. It builds an integrated closed-loop system of "authoritative evaluation, intelligent diagnosis, personalized empowerment, and iterative optimization" to realize theoretical localization, tool standardization, and empowerment precision.

Core theoretical foundation of the research

Constructivist learning theory

Constructivist learning theory is the core theoretical support for modern adult professional development, holding that learning is an active knowledge construction process rather than passive information reception. It emphasizes that effective learning must match learners' existing cognitive structure and real application scenarios, centered on individual developmental deficiencies [22]. This theory underpins the core logic of "diagnosis prior to empowerment" in this study. The improvement of teachers' AI literacy is not unified technical indoctrination, but an active competency construction process based on individual deficiencies in real teaching scenarios. Standardized and authoritative diagnostic tools are essential to accurately locate individual gaps and match personalized training paths to ensure targeted and effective professional development. Meanwhile, the feedback and situational principles of constructivism guide the design of the closed-loop iteration mechanism, supporting teachers' continuous optimization of technical application capabilities.

Technology-enhanced learning theory

The core logic of technology-enhanced learning (TEL) theory is that technology serves as a learning scaffold to compensate for learners' competency deficiencies and optimize learning effects, rather than replacing the dominant position of learners. It clarifies that effective technical empowerment must adapt to learners' competency levels and real application scenarios and avoid invalid technical superposition [23]. Based on TEL theory, this study defines the core positioning of intelligent agents. It takes teachers' competency deficiencies diagnosed by authoritative scales as the basis. It provides lightweight, scenario-adaptive, and targeted empowerment scaffolds. It matches differentiated training resources and practical tasks for

teachers with different literacy levels and at different educational stages. It eliminates the problems of technical redundancy and scenario disconnection in traditional training, and ensures that technology truly serves teachers' professional development.

Adaptive learning system theory

Adaptive learning system (ALS) theory is the direct theoretical basis for intelligent agent architectural design, with a core operational logic of "data collection, user portrait construction, competency analysis, content matching, and dynamic iteration". The four core modules of ALS directly guide the construction of the two-stage "recognition-response" intelligent agent in this study. The system builds teachers' literacy portraits based on authoritative scale data. It performs deficiency analysis via recognition agents and matches personalized resources through response agents. Dynamic iteration is realized relying on retest data, forming a complete adaptive empowerment chain that ensures the scientificity, personalization, and sustainability of intelligent system operation [24].

Policy theoretical basis: Zhejiang's dual framework for teachers' AI literacy

The 2025 dual framework of primary and secondary school and university teachers' AI literacy issued by Zhejiang Province is the core policy basis for local adaptation of this study. The trinity structure of basic literacy, applied literacy, and ethical norms defined by the policy is highly consistent with the six dimensions of the TAICS scale. Meanwhile, the framework distinguishes the differentiated scenario orientation of primary and secondary classroom teaching and university teaching and research. This study combines local policy standards with internationally authoritative evaluation tools to gain dual strengths of "local policy adaptation and international scientific standardization". It guarantees that the research findings are applicable to educational scenarios in Zhejiang, as well as academically standardized and universally valid.

Construction of three-dimensional teachers' AI literacy diagnosis model adaptable to all educational stages in Zhejiang

Four principles of model construction

(1) Policy adaptability principle

The model strictly aligns with national and Zhejiang provincial policies on teachers' AI literacy, fully covering the trinity core structure of official frameworks, and conforms to the cultivation orientation of regional teacher development to ensure consistency with regional educational development planning.

(2) Diagnosis-oriented principle

Centered on the accurate identification of individual teachers' competency deficiencies, the model dimensions fully adapt to the evaluation logic of the international authoritative TAICS scale. All indicators can be quantified through standardized scale data to accurately locate scenario-based competency defects, distinguishing it from the generalized definition of traditional standard-oriented frameworks.

(3) Full-stage hierarchical adaptation principle

Adopting the design logic of "unified core dimensions and differentiated scenario standards", the model maintains unified literacy dimension criteria. It distinguishes the practical scenario differences between primary and secondary classroom teaching and university teaching and research. It adapts to the job characteristics of teachers at all educational stages in Zhejiang Province and overcomes the adaptation defects of universal models.

(4) Closed-loop adaptation principle

The model dimensions and hierarchical indicators are completely aligned with the classification of intelligent agent resource libraries and scale evaluation dimensions. Scale diagnosis data can directly map training resources and improvement paths, seamlessly connecting diagnosis and empowerment links to support the implementation of the closed-loop mechanism.

Design of three-dimensional hierarchical indicator system

Combined with Zhejiang's official literacy framework, the core dimensions of the TAICS scale, and local teaching scenario characteristics, this study optimizes and constructs a localized three-dimensional teachers' AI literacy diagnosis system with subdivided secondary indicators. It adapts to standardized authoritative evaluation and differentiated scenario requirements for primary, secondary, and university teachers.

(1) Dimension 1: AI basic literacy (underlying competency diagnosis)

Corresponding to the AI knowledge cognition dimension of the TAICS scale, AI basic literacy is the prerequisite foundation for teachers' AI teaching application and ethical practice, focusing on teachers' AI cognition, basic operation, and data security capabilities, with three secondary indicators differentiated by educational stages.

a) AI value cognition and basic understanding: Master basic common sense of AI technology, clarify the application value and boundary of AI in education and teaching, and establish scientific technology application cognition. Primary and secondary teachers focus on classroom teaching tool cognition, while university teachers focus on AI technology cognition for teaching and research.

b) General AI tool operation capability: Proficiently master lightweight AI teaching tools adapted to stage scenarios, and independently complete basic teaching auxiliary tasks. Primary and secondary teachers adapt to courseware production, learning situation analysis, and homework correction tools; university teachers adapt to literature analysis, data processing, and curriculum optimization tools.

c) Data security and privacy literacy: Master the basic norms of educational data collection, desensitization, and application, clarify the boundary of teacher-student data privacy protection, avoid security risks in technology application, and meet the data management requirements of different educational stages.

(2) Dimension 2: AI applied literacy (core practical competency diagnosis)

Corresponding to the AI pedagogical application, AI teaching evaluation, and professional development dimensions of the TAICS scale, AI applied literacy serves as the core practical carrier of teachers' AI literacy. It focuses on the in-depth integration of AI technology into the whole teaching process and contains three secondary indicators.

a) AI-enabled teaching design capability

Combine learning situation characteristics and curriculum standards to carry out differentiated teaching design relying on AI tools, and optimize teaching activities and curriculum content to adapt to stage education goals.

b) AI-assisted classroom implementation capability

Integrate AI technology into the whole process of classroom interaction, learning situation collection, and teaching regulation to realize dynamic and personalized classroom teaching adapted to daily teaching scenarios.

c) AI-driven teaching evaluation and reflection capability

Use AI tools to carry out multi-dimensional teaching evaluation, excavate problems in teaching data, form evidence-based teaching reflection, and support continuous teaching optimization.

(3) Dimension 3: AI ethical normative literacy (value compliance diagnosis)

Corresponding to the AI ethics and humanistic education dimensions of the TAICS scale, AI ethical normative literacy acts as the value baseline and normative guarantee for AI-enabled teaching application. It focuses on the fairness, compliance and educational attributes of AI teaching practice and contains three secondary indicators.

a) Data privacy compliance capability

Strictly abide by educational data regulations, standardize the collection, storage, and application of teacher-student data, and ensure data security and compliance.

b) Algorithm bias identification and avoidance capability

Possess critical thinking on AI technology, accurately identify algorithm bias and content deviation in AI outputs, and manually intervene and correct technical results to ensure educational equity.

c) Technology education value adherence capability

Adhere to the people-oriented educational principle, reasonably control AI application boundaries, eliminate technology abuse, avoid replacing students' independent thinking, and uphold the essence of education.

Selection of standardized evaluation tools (authoritative scale adaptation)

This study abandons self-designed scales and adopts the internationally authoritative and mature TAICS scale as the sole standardized evaluation tool. Rigorously verified by reliability and validity tests, the scale is highly adapted to the three-dimensional diagnosis model of this study and can be directly applied to the AI literacy diagnosis of teachers at all educational stages in Zhejiang Province with outstanding scientificity and adaptability.

(1) Scale authoritative basis

Developed and verified by international educational

technology scholars in 2024, the TAICS scale adopts Delphi method, exploratory factor analysis, and confirmatory factor analysis for iterative optimization, finally forming a mature structure of 6 dimensions and 24 items. Verified by multi-regional and multi-stage large-sample data, its Cronbach's alpha coefficient, composite reliability, structural validity, and measurement invariance all meets excellent academic standards. It is one of the most recognized and adaptable authoritative scales in the field of teacher AI literacy evaluation, widely used in K12 and university teacher AI literacy research worldwide.

(2) Localized adaptation and optimization of the scale

Combined with the three-dimensional diagnosis model and local educational scenarios of Zhejiang Province, this study carries out localized adaptation optimization of the TAICS scale without modifying the core dimensions and item structure. It only adjusts academic expressions to fit domestic primary, secondary, and university teaching and research scenarios, forming two adapted versions for different educational stages. The localized adjustment ensures evaluation accuracy while completely retaining the original reliability and validity advantages of the authoritative scale.

(3) Scale evaluation specifications

The scale adopts the internationally universal 5-point Likert scoring method. Its evaluation dimensions correspond one-to-one with the three-dimensional diagnosis model of this study. It can accurately output teachers' total literacy scores and dimensional sub-scores and generate competency deficiency labels. It provides standardized and scientific data input for the "recognition-response" intelligent agent empowerment system, fundamentally solving the problems of insufficient scientificity and poor implementability of self-designed scales.

Model characteristics

Integrating local Zhejiang policies and international authoritative evaluation tools, this model has three core advantages. First, it has strong scientific standardization, relying on pre-verified authoritative scales to avoid academic defects of self-designed evaluation tools. Second, it achieves high local adaptability, aligning with provincial policy frameworks and fitting the teaching scenarios of all local educational stages. Third, it realizes integrated diagnosis and empowerment, with model dimensions and scale data fully connected with intelligent agent empowerment paths to support precise closed-loop empowerment.

Design of competency-driven intelligent agent system for teachers' AI literacy improvement

Overall design objectives of the intelligent agent

Based on three-dimensional diagnosis model indicators and TAICS standardized evaluation data, with multi-agent technology as technical support, this study develops a personalized empowerment intelligent agent. The agent takes teachers' competency deficiencies as the core, teaching scenarios as guidance, and closed-loop iteration as support. It seeks to resolve prominent drawbacks in conventional training: homogenization, separation from teaching scenarios and inadequate sustainable iteration, so as to fulfill four core goals: accurate competency diagnosis, scenario-based empowerment, lightweight deployment, and closed-loop optimization.

Three-tier overall architecture design of the intelligent agent

Drawing on well-established international multi-agent architectures, this study incorporates TAICS evaluation logic and three-dimensional model indicators to develop a layered collaborative architecture consisting of the learner layer, multi-agent core layer and resource library layer. Inter-layer data connectivity and coordinated task division are adopted to ensure precise empowerment.

(1) Architecture design basis

Guided by adaptive learning system theory and drawing on the authoritative design logic of FACET and LectūraAgents architectures, the system adopts a loosely coupled modular design. It takes standardized TAICS evaluation data as core input to realize standardized operations including data analysis, deficiency recognition, resource matching and iterative optimization.

(2) Detailed content of the three-tier architecture

a) First layer

Learner layer (user terminal). Collect and store teachers' basic attribute information, TAICS scale evaluation data, training behavior data, and teaching scenario characteristics, generate dynamic literacy portraits, and

identify relative competency deficiencies based on regional literacy norms.

b) Second layer

Multi-agent core layer (decision-making center). Consists of two functional sub-agents. The recognition sub-agent conducts multi-dimensional deficiency analysis based on scale data to generate standardized deficiency labels; the response sub-agent receives labels and matches personalized training paths and scenario-based practical tasks.

c) Third layer

Resource library layer (content support). Classify lightweight training resources and practical tasks strictly according to three-dimensional model dimensions, TAICS evaluation dimensions, and educational stage scenarios, realizing one-to-one accurate matching between deficiency labels and training content.

Two-stage operational logic of "recognition-response"

(1) Stage 1: Recognition sub-agent - accurate deficiency positioning driven by authoritative data

Taking TAICS standardized evaluation data as the core input, combined with teachers' scenario attributes such as educational stage, discipline, and teaching seniority, the system conducts hierarchical analysis through rule-based reasoning algorithms. It first judges the overall literacy level by comparing it with regional norms, then it refines competency deficiencies in each evaluation dimension. Finally, it generates standardized scenario-based deficiency labels to accurately locate teachers' specific shortcomings in AI basic literacy, applied literacy, and ethical normative literacy, providing data support for precise empowerment.

(2) Stage 2: Response sub-agent - adaptive personalized scheme generation

Receiving deficiency labels from the recognition sub-agent, the response sub-agent matches lightweight training resources and ladder practical tasks adapted to teachers' educational stages and discipline scenarios. It generates personalized training paths of "theoretical learning, simulation practice, and classroom implementation". It tracks real-time learning progress, records process data, and provides basis for subsequent effect re-test and system iteration.

Design of full-cycle closed-loop operational mechanism

This study constructs a complete five-link closed-loop system: "authoritative scale diagnosis, intelligent deficiency recognition, personalized training empowerment, effect re-test verification, and dynamic iterative optimization". Teachers complete standardized TAICS evaluation first; the intelligent agent identifies deficiencies and generates literacy portraits to match personalized training schemes. After phased training, teachers take the same scale re-test; the system adjusts empowerment strategies and resources matching logic dynamically based on pre-test and post-test data comparison, realizing continuous iterative improvement of teachers' AI literacy.

Design characteristics of the intelligent agent system

The core differentiated advantages of this intelligent agent are reflected in three aspects. First, authoritative data drives precise empowerment, adopting internationally mature standardized evaluation data to ensure diagnostic scientificity and avoid subjectivity of traditional empirical judgment. Second, scenario-based lightweight implementation adapts to local teaching scenarios of Zhejiang, reducing teachers' training burden and improving the practical conversion rate of training outcomes. Third, full-process closed-loop iteration breaks through the limitations of one-time training, realizing long-term dynamic tracking and continuous optimization of teachers' literacy and solving the traditional dilemmas of diagnosis-empowerment disconnection and training homogenization.

Empirical research plan of the system

Research objects and sampling methods

Adopting stratified cluster sampling, this study selects primary, secondary, and university teachers from urban and rural areas including Hangzhou, Ningbo, and Lishui in Zhejiang Province. The experimental group and control group are matched with consistent demographic characteristics to ensure sample representativeness, and the sample size meets the academic requirements of scale evaluation and statistical analysis.

Experimental design

This study adopts a quasi-experimental non-equivalent pre-test-post-test design with a 3-month intervention cycle. Both groups complete the localized adapted TAICS scale pre-test before intervention. The control group receives traditional homogenized training, while the experimental group adopts the intelligent agent

closed-loop empowerment system designed in this study. A post-test is conducted after intervention, and a delayed test is added to verify the long-term empowerment effect, so as to compare the literacy improvement differences between the two groups.

Observation indicators and data processing

Core quantitative indicators include the total score and three-dimensional sub-scores of teachers' AI literacy based on TAICS pre-test and post-test data. Supplementary indicators include teachers' technology application frequency, scenario integration quality, and training experience feedback. SPSS and SmartPLS are used for reliability and validity testing, difference analysis, and path analysis to ensure the scientificity and rigor of empirical conclusions.

Research innovations and discussion

Core research innovations

Theoretical innovation: This study constructs a three-dimensional diagnosis model integrating "international authoritative scale and local policy adaptation", breaking the dual defects of insufficient scientificity of domestic self-designed tools and poor adaptability of universal models. It unifies the standardization, localization, and precision of literacy diagnosis and improves the localized theoretical system of teachers' AI literacy diagnosis.

Tool innovation: This study builds a diagnosis-empowerment integrated link based on mature authoritative scales. It leverages standardized evaluation data to support precise empowerment of intelligent agents. This approach fundamentally addresses the long-standing practical issues of diagnosis-empowerment disconnection and blind empowerment in traditional research, and achieves seamless docking between evaluation data and teacher training paths.

Mechanism innovation: This study constructs a full-cycle closed-loop empowerment system driven by authoritative evaluation, integrating standardized diagnosis, intelligent empowerment, effect verification, and iterative optimization. It forms a replicable and popularized precise training paradigm for regional teachers' AI literacy improvement, providing a new practical path for intelligent teacher professional development.

Research discussion

Different from the traditional self-designed scale research paradigm, this study adopts the internationally recognized TAICS authoritative evaluation tool, greatly improving the academic standardization and conclusion credibility of the research. The scale dimensions are highly consistent with Zhejiang's local policy frameworks and three-dimensional literacy models, adapting to the evaluation needs of teachers at all local educational stages and accurately reflecting the current situation and deficiencies of local teachers' AI literacy. Subsequent empirical research will focus on verifying the local adaptation validity of the authoritative scale and the practical effect of intelligent agent empowerment, exploring the differentiated empowerment effect of the closed-loop mechanism on different teacher groups, and further optimizing the localized precise empowerment system.

Research limitations and future prospects

Research limitations

First, this study only completes the theoretical design of the model, intelligent agent architecture, and localized scale adaptation, without large-scale local empirical verification. The regional measurement validity of the scale and the practical empowerment effect of the intelligent agent need further verification. Second, the intelligent agent is currently in the theoretical design stage, and its technical implementability and resource adaptability need to be optimized through pilot practice. Third, the research is mainly adapted to Zhejiang's local scenarios, and its cross-regional universality needs further verification and improvement.

Future research prospects

Subsequent research will be improved in stages. First, carry out large-sample surveys to verify the local reliability and validity of the TAICS scale and optimize the three-dimensional diagnosis model. Second, complete the technical prototype development and hierarchical resource library construction of the intelligent agent to realize lightweight adaptive function deployment. Third, carry out regional pilot empirical research to iteratively optimize the empowerment mechanism and resource matching logic. Fourth, connect with provincial educational platforms to realize large-scale implementation, expand cross-regional adaptive

research, and finally form a national popularizable precise empowerment paradigm for teachers' AI literacy improvement in the intelligent education era [25].

Conclusion

Main research outcomes

Against Zhejiang's in-depth education digitalization drive and the nationwide promotion of teachers' artificial intelligence competency development, this study targets three prominent practical bottlenecks existing in current teachers' AI literacy cultivation. These bottlenecks include homogenized one-size-fits-all training modes, disjointed links between competency diagnosis and personalized targeted empowerment, and the scarcity of localized, diagnosis-oriented theoretical systems tailored to Zhejiang's local teaching contexts. Based on constructivist learning theory, technology-enhanced learning theory, and adaptive learning system theory, this study incorporates the internationally authoritative and empirically verified TAICS scale. It adopts a mixed research methodology that integrates literature analysis, policy interpretation, Delphi expert consultation, and systematic modular design. It completes the full set of theoretical modeling, indicator system construction and intelligent agent system architectural design work.

This paper constructs a localized three-dimensional AI literacy diagnosis system covering primary, secondary and university teachers across all educational stages. It differentiates AI basic literacy, AI applied literacy, and AI ethical normative literacy with hierarchical indicators tailored to stage-specific teaching scenarios. On this basis, this study constructs a three-layer collaborative intelligent agent framework, consisting of the learner layer, multi-agent core layer, and resource library layer. The framework supports core functions, including intelligent identification of teachers' competency gaps and matching of scenario-adaptive personalized training resources. Furthermore, the study constructs a full-cycle closed-loop empowerment mechanism that organically links standardized competency diagnosis, intelligent targeted training and dynamic effect iteration, forming a complete operation logic to realize continuous improvement of teachers' AI competency.

Theoretical and practical contributions

Theoretically, this research effectively supplements and enriches the localized diagnosis-oriented theoretical system of teachers' AI literacy in China, making up for the research gap that most existing domestic studies only focus on macroscopic competency standard formulation while ignoring individual deficiency identification. Practically, it delivers a set of standardized, scientifically reliable evaluation tools and operable intelligent agent system design solutions for primary and secondary schools, universities and local educational administrative authorities within Zhejiang Province. Relying on the integrated diagnosis and empowerment system, education departments can implement precise and differentiated teacher training. The system accurately identifies AI competency gaps among rural teachers, novice teachers and senior urban teachers, and narrows the overall literacy disparity among teachers to promote balanced and high-quality teacher development.

Research limitations

It should be noted that this work merely completes theoretical deduction and architectural design at the current stage, without large-scale regional empirical tests and practical pilot verification. The measurement invariance of the localized TAICS scale and the actual empowerment effect of the intelligent agent system still need to be verified through long-term quasi-experimental research.

Future research directions

Future research will carry out batch regional pilot experiments and collect real feedback from frontline teachers to optimize diagnostic indicators, resource matching algorithms and system operation logic. It will finally form a mature, replicable and popularized precise empowerment system suitable for regional teachers' AI literacy improvement. Overall, this study provides systematic theoretical support and actionable practical references for the targeted, high-quality cultivation of teachers' AI literacy in Zhejiang Province. It also offers innovative research ideas and implementable research paradigms for relevant domestic studies focusing on intelligent teachers' professional development in other regions of China.

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Conflicts of Interest

The authors declare no conflict of interest.

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