中華研究月刊 Chinese Studies Monthly

press

Research Article

https://doi.org/10.70731/kpbgm360

AI Empowerment Logic in the Digital Transformation of Chinese Language Education: From Tool Application to Ecological Reconstruction

人工智能赋能汉语教育数字化转型的逻辑：从工具应用到生态重构

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Keywords:
Chinese Language Education;
Artificial Intelligence;
Digital Transformation;
Ecological Reconstruction;
Human-AI Collaboration;
Educational Governance

关键词:
汉语教育；人工智能；
数字化转型；生态重构；
人机协同；教育治理

Abstract: With the coupled development of Generative Artificial Intelligence (GAI) and big data technologies, Chinese language education—especially international Chinese language education—is experiencing a critical leap from "information-assisted teaching" to "digital transformation." This study delves into the inherent evolutionary logic of AI empowerment in Chinese language education, arguing that its transformation path follows a three-stage progression: from efficiency-driven tool application in individual links, to full-process human-AI collaborative innovation, and ultimately to the systematic reconstruction of the educational ecosystem. The research elaborates on AI's profound impacts in reshaping learning paradigms, redefining teaching time and space, and enhancing teacher evaluation. It highlights that the essence of digital transformation lies in the reorganization of educational elements and the digital extension of educational sovereignty. Drawing on transnational cases and authoritative studies, this paper deconstructs the implementation paths of ecological reconstruction across four core dimensions: learning paradigms, resource development, evaluation systems, and governance mechanisms. Additionally, it offers forward-looking reflections on ethical challenges and technological boundaries in the current transformation, providing theoretical support and practical insights for building a high-quality, sustainable global digital ecosystem for Chinese language education.

摘要：随着生成式人工智能（GAI）与大数据技术的融合发展，汉语教育，尤其是国际中文教育，正在从“信息化辅助教学”迈向“数字化转型”的关键阶段。本文聚焦AI赋能汉语教育的内在演进逻辑，认为其转型路径呈现三阶段递进：由单一环节的效率型工具应用，发展到全流程的人机协同创新，最终走向教育生态的系统性重构。研究指出，AI正在重塑学习方式，重构教学的时空组织，并提升教师评价与改进的效能。数字化转型的本质在于教育要素的再组织，以及教育治理能力在数字空间的延伸。基于跨国案例与权威研究，本文从学习范式、资源开发、评价体系与治理机制四个维度梳理生态重构的实施路径，并对当前转型中的伦理风险与技术边界进行反思，为构建高质量、可持续的全球国际中文数字教育生态提供理论与实践参考。

Introduction

Amid the global wave of "educational digital transformation" advocated by UNESCO, the degree of digitalization in Chinese language education—an essential carrier for language dissemination and cultural exchange—has become a core indicator of educational modernization [9]. Data from the Center for Language Education and Cooperation (CLEC) shows that the

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Received 14 December 2025; Received in revised from 18 December 2025; Accepted 24 January 2026; Available online 31 January 2026.

global number of Chinese learners has exceeded 200 million. However, international Chinese language education has long grappled with three structural dilemmas: first, a severe shortage of qualified teachers, with high-quality educators concentrated in China and a handful of developed countries, resulting in a student-teacher ratio exceeding 1:50 in many developing nations; second, the high threshold for Chinese character acquisition, as the uniqueness and cultural load of pictographic characters leave overseas learners struggling with "difficulty in reading/writing and superficial understanding"; third, the lack of authentic cross-cultural communication contexts, leading to the phenomenon of "being able to learn but unable to apply" [2].

Traditional information-based methods, such as static multimedia courseware and recorded lectures, only improve dissemination efficiency without touching the deep-seated transformation of educational logic. For instance, early Chinese learning websites primarily presented static knowledge points, achieving cross-regional resource dissemination but retaining the traditional "teacher-centered" model, which fails to meet the needs of personalized learning and interactive communication [8]. The explosive development of AI, particularly Generative AI represented by Large Language Models (LLMs), has provided an opportunity for bottom-up reconstruction in Chinese language education. AI is no longer merely a "scaffolding" for teaching but has gradually evolved into the "gene" of the educational ecosystem—it not only addresses efficiency issues but also reshapes teaching relationships, resource forms, and evaluation logic [6]. Exploring the evolutionary logic of AI empowerment is theoretically and practically significant for constructing a high-quality, sustainable global Chinese language education system, aligning with the core agenda of "technology empowerment and cross-cultural competence development" in transnational education research [11].

The Evolutionary Path of AI Empowerment in Chinese Language Education: a Three-Stage Logic

Initial Stage: Efficiency Enhancement Under Instrumental Logic

At this stage, AI primarily enters the teaching process as an "assistant," with its core logic centered on **"technology substituting for efficiency"**—replacing teachers' repetitive tasks through technical tools to reduce teaching costs and improve the efficiency of basic links [10]. Technological application at this stage is characterized by "single-point breakthroughs and external empowerment," without altering the core structure of traditional teaching.

In practical terms, it focuses on the intelligent upgrading of three types of basic tasks: first, auxiliary tools for language input and output, such as Optical Character Recognition (OCR) technology for digitizing and retrieving paper textbooks and ancient documents, helping learners quickly look up rare or polyphonic characters; Text-to-Speech (TTS) technology for generating standard Mandarin, Cantonese, and other accent streams to provide pronunciation references for overseas learners; and Automatic Speech Recognition (ASR) technology for developing Putonghua proficiency test simulation systems that real-time correct pronunciation issues such as tones and phonological changes [5]. Second, basic teaching management tools—for example, AI essay grading systems can automatically identify Chinese character writing errors and grammatical mistakes, generating basic revision suggestions to free teachers from heavy homework grading; course management platforms use AI to track attendance and learning duration, simplifying teaching administration. Third, resource retrieval tools, such as digital textbook and question banks that support quick filtering by knowledge points and difficulty levels, addressing the inefficiency of resource searching in traditional teaching [8].

At a deeper level, technological application at this stage is essentially "tool substitution"—AI acts as an externally inserted auxiliary means to solve high-repetition, low-creativity tasks in teaching. At this point, the physical field (classroom) and logical field (teachers imparting knowledge) of teaching remain unchanged; technology only plays a role in "improving efficiency and reducing burden," primarily alleviating the burden of "teaching" but failing to address core pain points of "learning," such as meeting personalized needs and constructing cultural contexts [3]. This logic of instrumental application is consistent with the principle of "complementarity between economic and teaching activities" in educational institutions, achieving a balance between improved teaching efficiency and resource cost control through technological optimization [12].

Developmental Stage: Human-AI Collaboration Under Integration Logic

With the maturity of adaptive algorithms and Natural Language Processing (NLP) technology, AI has begun to deeply intervene in the "learning" process, shifting its core logic from "efficiency substitution" to **"data-driven precision"**, realizing the initial reorganization of teaching elements and process reengineering [1]. At this stage, AI is no longer an isolated tool but forms a col-

laborative relationship with teachers and students, becoming an indispensable core element in the teaching process.

In practice, AI's application scenarios have expanded from "teaching assistance" to "learning empowerment": first, personalized learning path planning—constructing Chinese grammar and vocabulary systems based on knowledge graph technology, accurately identifying learners' knowledge gaps (such as preposition usage errors and Chinese character stroke order issues) through entrance assessments, and dynamically adjusting learning content and difficulty gradients [10]. For example, the AI system of an international Chinese education platform can strengthen tone discrimination training for Southeast Asian learners who struggle with tone perception, and push stroke order animations and interactive writing exercises for European and American learners who face difficulties in Chinese character writing. Second, intelligent Q&A and companion learning—Chinese intelligent teaching assistants developed based on large language models can provide 24/7 real-time responses, answering learners' questions about vocabulary, grammar, and cultural backgrounds, and even simulating real dialogue scenarios for oral practice [6]. Third, teaching decision support—by analyzing learners' learning behavior data (such as answer accuracy, learning duration, and interaction frequency), AI generates learning situation analysis reports for teachers, highlighting key knowledge points that require emphasis and student groups that need attention, enabling teachers to implement precise teaching [4].

At a deeper level, the core transformation at this stage is the "reconstruction of teaching relationships": the teaching process has shifted from "group uniformity" to "large-scale personalization." AI acts as a digital twin of teachers, undertaking tasks such as learning situation diagnosis, personalized push, and basic Q&A, while teachers focus on high-level links such as teaching design, cultural guidance, and emotional support [7]. Data has become the blood connecting teachers, students, and resources, forming a teaching closed loop of "diagnosis-push-feedback-optimization," marking the transformation of Chinese language education from "experience-driven" to "data-driven" [3]—a shift that also provides a new path for "precision competence development" in cross-cultural Chinese learning [11].

Advanced Stage: Systematic Reconstruction Under Ecological Logic

This is the ultimate goal of digital transformation. AI is no longer an isolated module but a technical foundation integrated into the educational ecosystem, with its core logic centered on **"digitally endogenous paradigm reshaping"**, achieving a leap from teaching link optimization to comprehensive educational system reconstruction [2]. At this stage, the logic of technological empowerment has transcended tool application itself, rising to profound changes in organizational structure, evaluation logic, educational boundaries, and educational sovereignty.

In practical terms, ecological reconstruction is reflected in three types of innovative scenarios: first, the construction of immersive and collaborative learning environments—creating "digital twin classrooms" through VR/AR technology, allowing global learners to jointly participate in Chinese teaching activities in virtual reality. For example, simulating traditional Chinese festival scenarios (such as pasting Spring Festival couplets and making zongzi during the Dragon Boat Festival) to learn language and experience culture through interactive experiences; using multimodal interaction technology to achieve real-time cross-regional collaboration, enabling overseas learners to team up with Chinese students for project-based Chinese learning (such as co-producing Chinese Vlogs and conducting cross-cultural research) [6]. Second, the construction of a decentralized resource ecosystem—building an open-source Chinese education platform based on AI, encouraging teachers and learners worldwide to participate in resource creation and optimization. AI is responsible for semantic annotation, quality review, and precise distribution of resources, forming a "co-construction, sharing, and dynamic evolution" resource ecosystem [5]. Third, the construction of a new educational governance system—establishing a blockchain and AI-based academic credit certification and evaluation system to realize the mutual recognition of Chinese learning achievements among different institutions and countries; using AI to monitor the fair distribution of educational resources, promoting the tilt of high-quality digital resources toward developing countries [9].

At a deeper level, the educational ecosystem at this stage has transformed from "closed and hierarchical" to "open and platform-based": school boundaries have blurred, with informal learning (such as short-video Chinese learning and AI companion practice) deeply integrating with formal learning (classroom teaching and credit courses); educational subjects have diversified, with governments, schools, enterprises, and learners jointly participating in ecological construction; educational sovereignty has achieved digital extension—China enhances its discourse power and influence in global Chinese language education by exporting digital standards, core technologies, and high-quality resources [2]. This process of ecological reconstruction

fully reflects the "in-depth complementarity between economic and teaching activities" in educational institutions— the economic attributes of technical platforms provide sustainable support for teaching activities, while the high-quality output of teaching activities feeds back the optimization of the platform ecosystem [12].

Core Dimensions and Logical Implementation of Ecological Reconstruction

Reconstruction of Learning Paradigms: From "Acquisition" to "Symbiosis"

Traditional Chinese learning emphasizes rote memorization and repetitive practice, with learners often in a passive receptive state, making it difficult to form genuine language competence and cultural perception [8]. Ecological reconstruction empowered by AI advocates **"embodied learning" and "adaptive learning"**, realizing a fundamental transformation of learning paradigms [4].

The core of embodied learning is "situationalization and experientialization." Through multimodal interaction technology, AI can create authentic communication contexts for students, transforming Chinese learning from mere symbol memory to semantic understanding and cultural perception. For example, for business Chinese learners, AI can simulate workplace scenarios such as job interviews, business negotiations, and product introductions, allowing learners to interact with AI through multimodal methods (voice, text, body language) to master professional vocabulary and communication etiquette in practice; for adolescent learners, AI can construct Chinese adventure game scenarios where learners advance through solving language puzzles and completing Chinese tasks, improving language application ability in immersive experiences [10]. Adaptive learning emphasizes "personalization and dynamic adjustment"—based on learners' cognitive characteristics, learning progress, and interests, AI real-time adjusts learning content and methods. For visual learners, it pushes more image and video resources; for auditory learners, it strengthens audio materials and oral practice; for fast-progressing learners, it adds extended content; for learners facing difficulties, it provides step-by-step guidance and encouraging feedback [6].

This paradigm shift transforms learners from passive recipients into active explorers and creators in the digital environment. Chinese learning changes from "being forced to learn" to "wanting to learn," and from "learning to know" to "learning to use," truly realizing the synchronous improvement of language competence and cultural literacy [2]—aligning with the core perspective of "cultivating cross-cultural competence through situational learning" in transnational education research [11] (**Figure 1**).

Reconstruction of Resource Development: From "Static Textbooks" to "Dynamic Semantic Libraries"

Traditional Chinese education resources are centered on paper textbooks, with three limitations: first, outdated content updates, as textbook content often fails to keep up with the real-time development of Chinese and social hot topics; second, serious homogenization, making it difficult to meet the personalized needs of different regions and learning objectives; third, weak interactivity, with learners only able to passively read without in-depth participation [5]. Digital transformation requires resources to be highly interactive and semanticized. AI technology provides core support for the reconstruction of resource development [1].

AI-empowered resource development presents three major transformations: first, the shift in resource production logic from "expert compilation and one-way distribution" to "AI-assisted, multi-stakeholder co-construction, and dynamic generation." By capturing real-time Chinese corpora from the entire network, AI can dynamically generate Chinese reading materials suitable for learners' proficiency levels, completely solving the problem of outdated textbooks and content disconnected from real life [10]. For example, for learners interested in China's technological development, AI can automatically screen recent Chinese technology news, simplify complex sentence structures, and label key vocabulary before pushing; for learners preparing for the HSK exam, AI can generate simulation questions that match the exam difficulty and question types. Second, the diversification of resource forms—shifting from single text and image resources to multimodal, interactive resources. AI can transform classic literary works into audio books, animated short films, or interactive scripts, and Chinese character teaching into stroke order games and radical puzzles, enhancing resource attractiveness and participation [8]. Third, the precision of resource distribution mechanisms—achieving "one-size-fits-one" resource push based on knowledge graph and user portrait technology. Chinese education platforms can automatically match the most suitable learning resources according to learners' progress (such as mastered vocabulary and grammar points), learning objectives (such as HSK exams, business communication, or cultural experience), and interests (such as sports, art, and food), preventing learners from "getting lost" in massive resources [3].

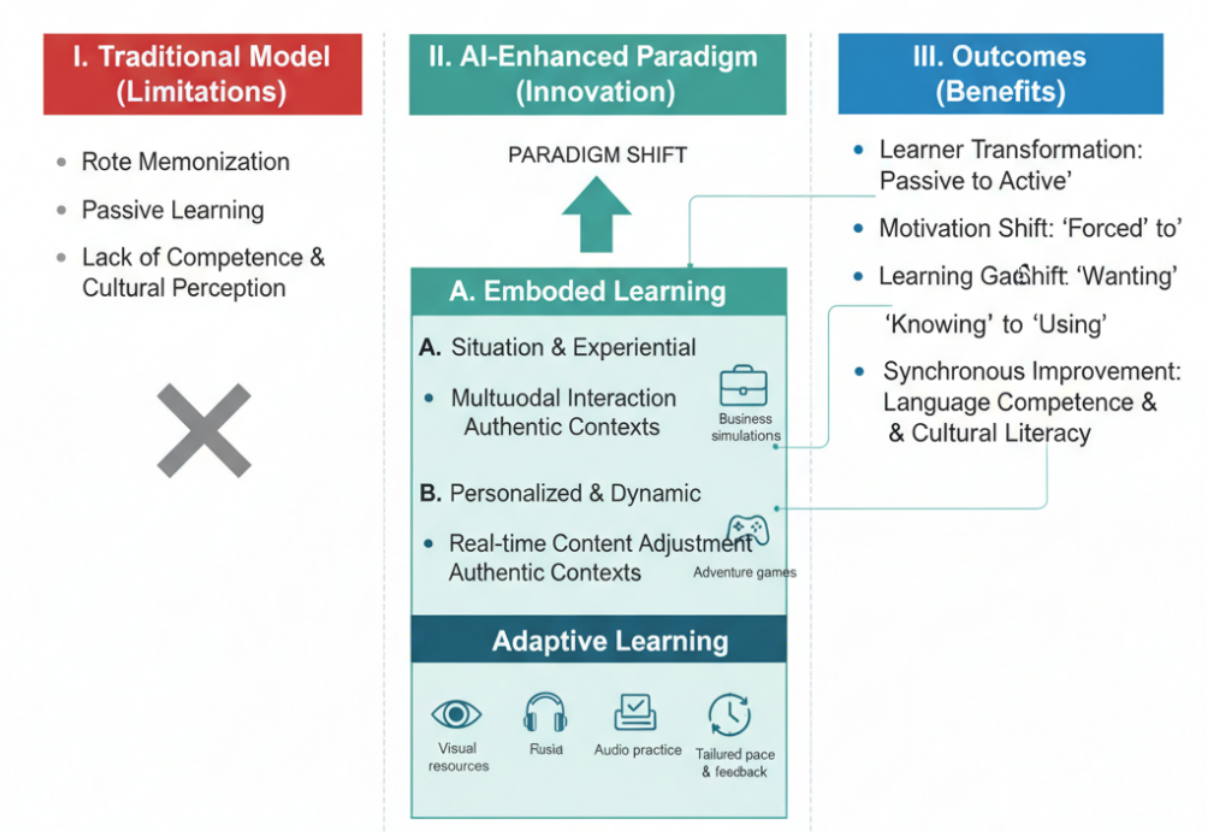

Figure 1 | AI-Empowered Transformation of Chinese Language Learning

The construction of such dynamic semantic libraries enables Chinese education resources to break through time and space constraints, achieving unlimited expansion and precise supply, laying the foundation for the balanced development of global Chinese language education [9]. Meanwhile, it realizes the precise alignment between teaching activities and market demands through "dynamic resource updates," reflecting the complementarity between economic and teaching activities in educational institutions [12] (**Figure 2**).

Reconstruction of Evaluation Systems: From "Summative Scores" to "Full-Process Profiles"

Traditional Chinese education evaluation is centered on summative assessments (such as the HSK exam and final classroom exams), with a single evaluation standard and closed evaluation process. It is difficult to fully reflect learners' language competence and learning processes, and suffers from the drawbacks of "valuing knowledge over ability" and "valuing results over processes" [4]. The development of AI technology provides technical support for the reconstruction of evaluation systems, making "full-process, multi-dimensional, and personalized" evaluation possible [7].

The reconstruction of AI-empowered evaluation systems is reflected in three dimensions: first, the comprehensive collection of evaluation data—AI can real-time track micro-data during learners' language input, output, and interaction processes, including pronunciation accuracy, vocabulary richness, grammatical correctness, and expression fluency. It can even capture non-verbal information such as facial expressions and body language through cameras, comprehensively reflecting learners' language competence and learning status [6]. For example, in oral evaluation, AI can not only identify pronunciation errors but also analyze phonological changes, intonation fluctuations, and emotional expression, providing a more comprehensive assessment; in writing evaluation, AI can analyze multiple dimensions such as content completeness, logical coherence, language standardization, and expression innovation, rather than merely focusing on grammar and spelling errors [10]. Second, the dynamicization of evaluation methods—shifting from "one-exam-determines-all" to "full-process continuous evaluation." By continuously collecting learners' learning data, AI generates dynamically updated "Chinese proficiency profiles," clearly showing learners' strengths and weaknesses, progress trajectories, and development potential, enabling learn-

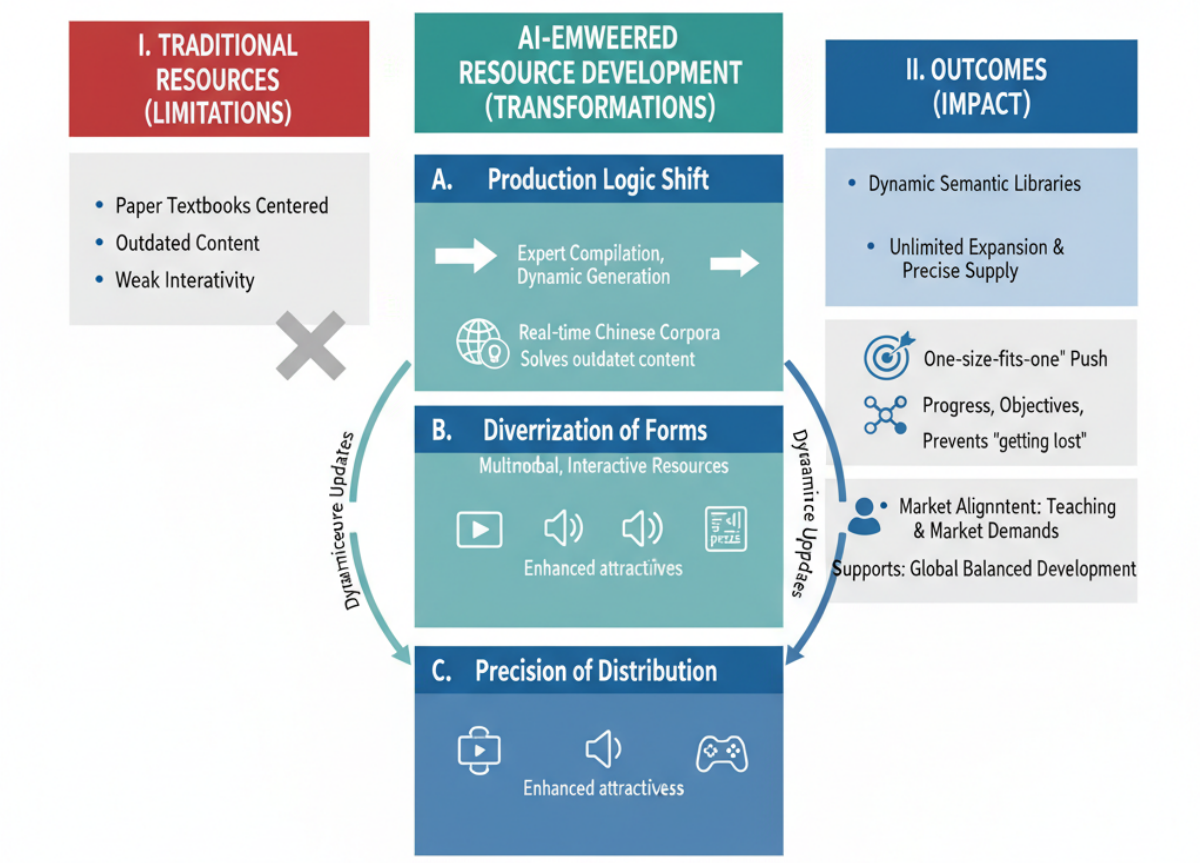

Figure 2 | AI-Empowered Resource Development for Chinese Language Education

ers and teachers to timely understand learning effects and adjust learning and teaching strategies [3]. Third, the transformation of evaluation functions—from "screening and differentiation" to "diagnosis and empowerment." Evaluation results are no longer merely scores and rankings but specific ability analysis reports and personalized improvement suggestions. For example, AI can recommend relevant grammar explanations and exercises for learners' preposition usage errors, and push targeted pronunciation training resources for pronunciation problems, making evaluation an important link to promote learning [4].

This reconstruction of the evaluation system shifts the focus of Chinese language education from "knowledge indoctrination" to "ability cultivation," and from "result-oriented" to "process-oriented," truly realizing the deep integration of evaluation and teaching [2], and providing technical support for "precise ability profiling" of cross-cultural Chinese learners [11] (**Figure 3**).

Reconstruction of Governance Mechanisms: From "Single Management" to "Multi-Stakeholder Collaboration"

Traditional Chinese education governance takes governments and schools as core subjects, with a relatively closed governance model characterized by delayed decision-making, uneven resource distribution, and supervision difficulties [9]. Ecological reconstruction empowered by AI promotes the transformation of governance mechanisms from "single management" to "multi-stakeholder collaboration," constructing a new governance system of "government guidance, market-driven, school-led, and social participation" [1].

Specifically, the reconstruction of governance mechanisms is reflected in three levels: first, the digital transformation of government governance—governments build big data platforms for Chinese language education to real-time monitor the global development of Chinese language education (such as learner scale, teacher distribution, and resource usage), providing data support for policy formulation; they formulate application standards, ethical norms, and data security rules for AI in Chinese language education to guide the orderly devel-

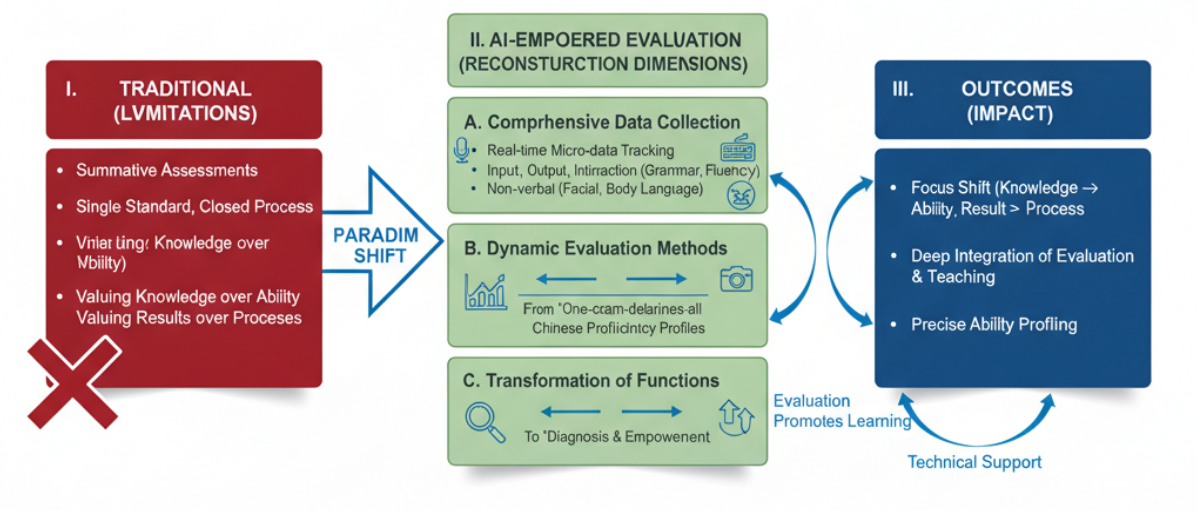

Figure 3 | AI-Empowered Evaluation System Reconstruction for Chinese Language Education

opment of digital transformation [9]. For example, the "Action Plan for International Chinese Online Education (2021-2025)" issued by the CLEC clearly proposes to "establish an international Chinese education digital standard system and regulate the application of AI technology" [9]. Second, the collaborative governance between markets and schools—deep cooperation between AI enterprises and Chinese education institutions, with enterprises focusing on technology R&D and resource supply, and schools focusing on teaching innovation and talent training, forming a "demand-oriented, complementary advantage" cooperation mechanism [6]. For example, technology companies and universities collaborate to develop specialized large models for Chinese language education, combining universities' teaching experience with enterprises' technological advantages to create intelligent products more in line with teaching needs; schools obtain high-quality resources and technical support through the use of enterprise digital platforms, while providing teaching scenarios and data feedback for enterprises to promote technological iteration [3]. This cooperation model not only optimizes teaching effects but also realizes the market-oriented efficient allocation of educational resources, fully reflecting the complementarity between economic and teaching activities in educational institutions [12]. Third, the widespread participation of society—encouraging Chinese teachers, scholars, and learners worldwide to participate in the formulation of Chinese education standards, resource construction, and quality supervision through open-source communities and crowdsourcing platforms, forming a "co-construction, co-governance, and shared" governance pattern [5].

This multi-stakeholder collaborative governance mechanism breaks the closedness and hierarchy of traditional governance, improving the precision, efficiency, and fairness of Chinese language education governance, and providing institutional guarantee for the global digital transformation of Chinese language education [2] (**Figure 4**).

Challenges and Reflections: the Boundaries of Technological Rationality

Despite the clear logic and broad prospects of AI empowerment in Chinese language education, three core challenges remain in practice, requiring us to grasp the boundaries of technological rationality and achieve a balance between technological empowerment and humanistic care [4].

The Challenge of Digital Divide and Educational Equity

Unequal distribution of technical resources may widen the "gap between the rich and the poor" in global Chinese language education, exacerbating educational inequality [9]. On one hand, there is a significant gap in hardware facilities—learners in developed countries generally have access to high-speed networks and intelligent terminals, while some regions in developing countries still face insufficient network coverage and equipment shortages, making it difficult to access AI-empowered high-quality educational resources. On the other hand, there is a clear gap in digital literacy—teachers and learners in different regions vary in AI tool application capabilities, data literacy, and critical thinking. Some teachers may struggle to effectively use AI

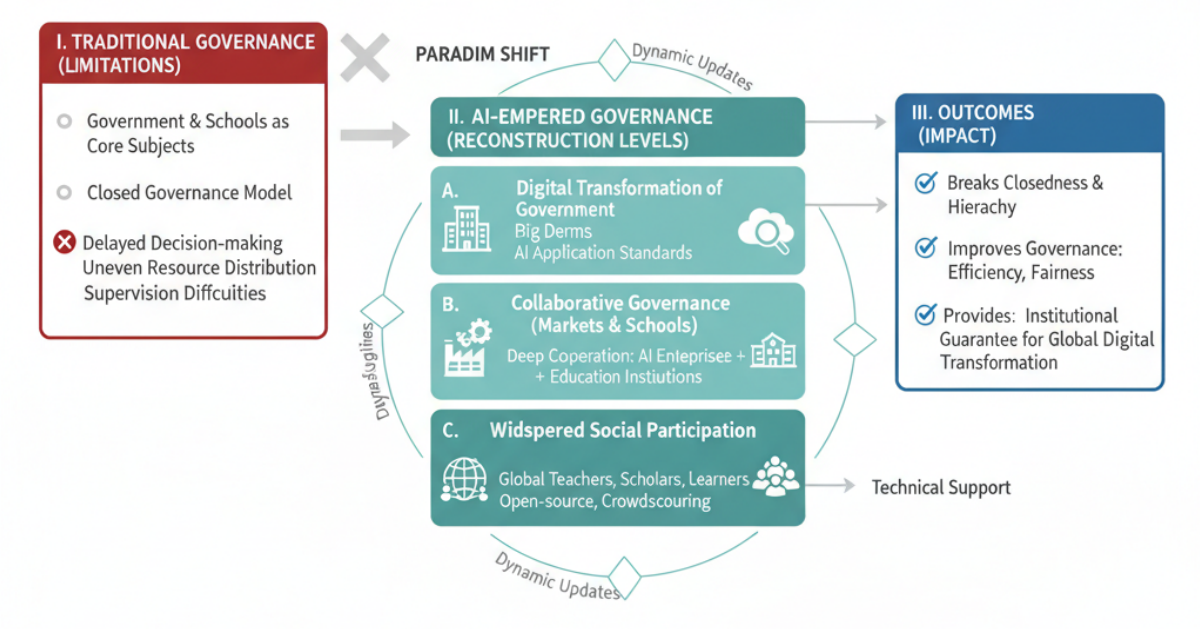

Figure 4 | AI-Empowered Governance Reconstruction for Chinese Language Education

technology due to insufficient digital literacy, while some learners may fall into "technological dependence" without guidance [7]. This digital divide may further expand the development gap in Chinese language education, violating the basic concept of "educational equity" [2] and affecting the foundation of "equal participation" in transnational Chinese education [11].

The Risk of Losing Cultural Subjectivity

Chinese language education is not only language teaching but also an important carrier for cultural dissemination, with its core goal of cultivating learners' Chinese competence and Chinese cultural literacy [8]. Over-reliance on AI algorithms for content generation may lead to the oversimplification or misinterpretation of the profound cultural connotations behind Chinese—AI-generated Chinese materials may only focus on the correctness of language forms while ignoring the transmission of cultural connotations; AI-simulated communication scenarios may lack authentic cultural contexts, resulting in learners' superficial understanding of Chinese [5]. More seriously, if AI algorithms' training data contains Western-centric cultural biases, it may subtly influence learners' perception of Chinese culture, weakening the cultural communication function of Chinese language education [6]. How to uphold cultural subjectivity in technological empowerment and avoid "language instrumentalization and cultural superficialization" is a core issue that must be addressed in the digital transformation of Chinese language education [2]—a problem that is particularly prominent in transnational education scenarios [11].

The Ethical Dilemma of Algorithmic Bias and Privacy Protection

The application of AI in Chinese language education involves the collection and analysis of large-scale learning data, which includes sensitive content such as learners' personal information, learning behaviors, and language abilities. Improper data security management may lead to privacy leaks [7]. For example, learners' voice data and facial information may be illegally collected and misused, triggering privacy infringement issues; the commercial use of learning data may violate learners' intellectual property rights and personality rights [4]. Meanwhile, algorithmic bias may lead to unfair teaching outcomes—if AI training data contains regional, gender, or cultural biases, it may result in biased resource recommendations and evaluation results, such as stereotypes about the language expression of learners from developing countries, affecting the fairness of evaluation [6]. How to regulate data collection and use and prevent algorithmic bias is an ethical red line that must be upheld in AI-empowered Chinese language education [9].

Conclusions

The logic of AI empowerment in the digital transformation of Chinese language education is a dynamic process evolving from technological application to eco-

logical development: the instrumental stage addresses the problems of uneven resources and low efficiency in traditional Chinese language education through "efficiency substitution"; the integration stage achieves teaching precision and personalization through "data-driven" approaches, reconstructing human-AI collaborative teaching relationships; the ecological reconstruction stage builds an open, collaborative, and diverse new ecosystem for Chinese language education through "paradigm reshaping," realizing the comprehensive reorganization of educational elements and the sublimation of educational value.

The essence of this transformation is the evolution of Chinese language education from a traditional "closed classroom" to a "global ecosystem," from "knowledge transmission" to "ability cultivation and cultural dissemination," and from "experience-driven" to "data and technology-driven". In the future, Chinese language education should actively embrace AI-driven ecological reorganization on the basis of adhering to "humanism": on one hand, strengthen technological innovation, promote the deep integration of AI and Chinese teaching, and continuously optimize learning paradigms, resource systems, evaluation mechanisms, and governance models; on the other hand, uphold the essence of education, prevent digital divide, cultural loss, and ethical risks, and achieve a balance between technological rationality and humanistic care. Only in this way can we truly build a more equitable, efficient, and humanistic global Chinese language education environment, promoting Chinese language education to leap from traditional educational civilization to digital educational civilization and making greater contributions to the exchange and mutual learning of human civilizations.

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