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Conceptual Paper

From Empirical Reflection to Intelligent Diagnosis: Generative AI-Assisted Pedagogical Reform for Rural Teachers

Shengjie Shui[1], Chang Li[2,*]
[1]School of Fashion, Henan University of Engineering, Zhengzhou 451191, China
[2]School of Intelligent Perception and Instrumentation, Zhongyuan University of Technology, Zhengzhou 450007, China
[*]**Correspondence:** Chang Li, changl_work@163.com

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Abstract
Rural education has long confronted the practical dilemma of a scarcity of professional pedagogical and research support, constraining teachers to superficial, empirical-level reflection. Generative Artificial Intelligence (GenAI) provides a technological pathway to dismantle this bottleneck. Grounded in the TPACK theoretical framework, this conceptual and design-based study deeply integrates GenAI as a digital scaffold throughout rural teachers' pedagogical optimization. The research constructs an intelligent assistance system comprising data normalization, structured prompting, and differentiated feedback. By reconstructing a pedagogical reform case in elementary mathematics, the study hypothesizes the transformational trajectory from traditional empirical reflection toward intelligent diagnosis. The proposed system aims to identify cognitive disconnections and generate dynamic verification scaffolds to bridge the logical chasm in instructional sequences. To mitigate technological alienation, this study establishes a "Human-in-the-Loop" (HITL) collaborative review principle and proposes safeguarding mechanisms for data privacy and algorithmic dependency. Ultimately, this study suggests the feasibility of transitioning to data-driven paradigms, providing theoretical support for enhancing rural teachers' competencies.

Keywords
generative artificial intelligence, intelligent diagnosis, rural teachers, pedagogical reform

1. Introduction

The technology-driven educational paradigm shift is propelling global rural education into a phase of digital transformation. Relevant government departments and educational administration agencies in China have explicitly proposed strategic initiatives to expand high-quality basic education and promote digitalization. These initiatives mandate the normalized and effective implementation of online pedagogical research across regions to elevate the competency and professionalization of rural teachers. From an international perspective, the quality of professional practice and the capacity to access training resources among in-service rural teachers have similarly garnered significant attention (Subramaniam, 2023). The majority of traditional teacher training programs are centered on urban contexts, leaving rural teachers bereft of effective pedagogical tools to navigate complex local environments (Pachón Porras, 2024). The structural imbalance of urban-rural educational resources necessitates that academia explore cross-spatiotemporal teaching and research mechanisms. Remote mentoring models, scaffolded by modern technology, possess the potential to overcome geographical barriers and professional resource fortresses (Randolph et al., 2025). Cultivating a high-quality cohort of rural teachers plays a decisive role in deepening curriculum reform and enhancing instructional quality.

Rural teachers encounter multiple structural barriers throughout their professional growth. The sense of isolation and the dearth of professional development opportunities induced by geographical distance directly constrain the enhancement of their pedagogical competencies. As empirically demonstrated by Subramaniam (2023), in-service educators in remote areas face systemic challenges dominated by geographic isolation, severe time constraints, and a chronic lack of relief or substitute staff to cover professional development sessions; yet, their professional efficacy heavily relies on mentoring within a supportive learning atmosphere. Lacking instantaneous guidance from senior pedagogical experts, rural teachers frequently operate in a state of isolation when applying digital technologies and conducting instructional design. Current pedagogical reflection practices predominantly stagnate at the level of fragmented empirical descriptions, lacking systematic evidentiary support and deep cognitive processing (Lu & Chen, 2025). Such experience-oriented, superficial reflection struggles to translate into substantive instructional improvement strategies. Consequently, rural teachers urgently require a novel pedagogical support model capable of providing immediate feedback and professional guidance under structural constraints.

Generative Artificial Intelligence (GenAI) provides a viable technological pathway for rural educational innovation. This technology is capable of reconstructing the human-AI pedagogical synergistic relationship. By undertaking routine content generation and preliminary analytical tasks, AI enables teachers to concentrate on adaptive guidance and the cultivation of higher-order thinking (Balraj, 2025). In regions characterized by a scarcity of educational resources, AI exhibits the application potential to deliver at-scale mentoring and support for teachers' professional practices (Reimers et al., 2026). This study aims to construct an intelligent diagnostic system assisted by GenAI, which translates teachers fragmented, empirical reflective texts into data-driven, precise diagnostic reports (Lu & Chen, 2025). The system design strictly establishes a "Human-in-the-Loop" (HITL) interactive paradigm. Feedback content generated by AI must undergo human cognitive calibration and cultural sensitivity assessment, thereby preserving the teacher's status as the core architect in instructional evaluation and design (Kamarulzaman, 2026).

Through systemic intelligent interventions, this study seeks to dismantle the resource bottlenecks in rural teachers' professional development, realizing a pedagogical reform for rural teachers that transitions from empirical reflection to intelligent diagnosis. To guide this conceptual exploration, the study addresses the following research questions:

(1) How can an intelligent diagnostic system, grounded in the AI-TPACK framework, be systematically constructed to support rural teachers?

(2) In what ways might GenAI act as a digital scaffold to transform empirical instructional designs into logical, data-driven frameworks?

(3) What safeguarding mechanisms are necessary to mitigate the risks of technological alienation and ensure teachers' professional agency in an AI-assisted ecosystem?

2. Intelligent Diagnostic System Based on AI-TPACK and Digital Scaffolding

Technological Pedagogical Content Knowledge (TPACK) serves as the objective benchmark for evaluating teachers' instructional design capabilities. The intervention of GenAI has propelled the evolution of this model into the Artificial Intelligence Technological Pedagogical Content Knowledge (AI-TPACK) framework (Al-Abdullatif, 2024), which deeply embeds AI literacy within the domains of pedagogical and content knowledge. Pre-service and in-service teachers frequently leverage AI tools to design curricula and create learning activities; during this process, AI systems act as pedagogical partners, supporting teachers' knowledge integration (Saputra et al., 2025). Within the rural educational context, due to constrained professional support, lesson plans produced by teachers often exhibit loosely structured characteristics driven by empirical orientation. The AI-TPACK framework provides core indicators for identifying these deficiencies. By analyzing the degree of alignment between technological methods and pedagogical objectives, the diagnostic system identifies logical disconnections within the discipline and the misuse of technological tools. This theoretical benchmark ensures the scientific rigor of the diagnostic system's evaluation indicators, establishing a structured prerequisite for the dimension setting in subsequent sections.

GenAI exerts the interventional role of a digital scaffold during the lesson plan optimization process. Technological systems construct a structured conduit for teachers to transcend their current cognitive levels. Large Language Models (LLMs) translate experts' evaluative logic into machine directives via prompt engineering, where precise prompt design can significantly enhance the explanatory quality of generated content (Aruleba et al., 2026). In the pedagogical diagnosis phase, the system utilizes prompt engineering to analyze the logical structure of instructional texts. The intervention of digital scaffolds permeates the entire process of planning, drafting, and revising; this intervention effectively elevates the textual quality and logical rigor of instructional designs (Pebriana, 2025). Teachers' original empirical reflections are transformed into standardized pedagogical strategy designs through systemic regulation. This external guidance mechanism not only provides feedback information but also reshapes teachers' professional reflective trajectories via collaborative regulation mechanisms (Tsakeni et al., 2025). This mechanism directly underpins the specific implementation steps for the subsequent reconstruction of pedagogical reform cases.

Intelligent-assisted instructional design must adhere to the HITL interactive principle. While AI possesses efficiency advantages in generating fundamental architectures and diverging proposals, un-intervened automated texts are prone to issues such as lower-order cognitive thinking and a lack of situational empathy. Furthermore, the output results exhibit limitations regarding content accuracy and contextual adaptability; therefore, the ultimate quality of instructional design hinges on human intervention. Teachers must adjust intelligent feedback through reflection-in-action and integrate local cultural values into the evaluation process (Kamarulzaman, 2026). To further compensate for machine limitations, teachers need to conduct real-time adjustments and critical evaluations during the application process (Dewi, 2025). Human-machine synergistic theory redefines the role division of pedagogical subjects: AI handles routine content generation and preliminary analysis, while teachers are responsible for adaptive guidance, emotional support, and value judgment (Balraj, 2025). This paradigm delineates the boundary between machine computation and professional judgment, establishing the core status of teachers within the technologically synergistic environment. This perspective constitutes the underlying logic of the verification phase within the diagnostic system, ensuring that technological application serves deep conceptual learning. To systematically consolidate these theoretical foundations, Table 1 provides a comprehensive support matrix that delineates the core elements and functional positioning of AI-TPACK, Digital Scaffolding, and the HITL paradigm within the intelligent diagnostic system.

Table 1

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Support Matrix of Theoretical Perspectives on the Intelligent Diagnostic System

Theoretical Dimension	Core Elements	Functional Positioning within the Intelligent Diagnostic System	Key Literature Support
AI-TPACK	Integration of AI literacy and disciplinary knowledge	Establishing structured evaluation indicators for diagnostic tasks	Al-Abdullatif (2024), Saputra et al. (2025)
Digital Scaffolding	Prompt engineering and system-level regulation	Providing an external conduit for the structural reorganization of lesson plan texts	Pebriana (2025), Aruleba et al. (2026)
Human-in-the-Loop	Reflection-in-action and critical evaluation	Maintaining the boundary between machine computation and teachers' professional judgment	Kamarulzaman (2026), Balraj (2025)

3. Methodology

This study employs a conceptual and design-based research methodology to explore the potential of GenAI in rural educational contexts. Given the nascent stage of deep AI integration in rural areas, the research relies on the theoretical reconstruction of an authentic pedagogical case rather than large-scale empirical data collection. The "Pigeonhole Principle" from a sixth-grade mathematics curriculum was purposively selected as the illustrative case because its high demand for abstract logical reasoning provides a rigorous context for testing AI's diagnostic capabilities. Regarding technical implementation, the proposed system conceptualizes the use of advanced LLMs. The implementation framework relies on zero-shot and few-shot prompt engineering techniques tailored to pedagogical standards. This approach explicitly highlights the integration of AI and data analysis within educational research, systematically transforming unstructured pedagogical texts into standardized features.

Furthermore, to address ethical constraints, the designed data normalization process explicitly incorporates automated anonymization protocols that strip all personally identifiable information (PII) from teachers' input data prior to algorithmic processing. While this design-based approach provides a robust theoretical framework, it is acknowledged that the current findings represent hypothesized interventions and require future empirical validation through classroom observations and teacher interviews.

4. Construction of a Generative AI-Assisted Intelligent Diagnostic System

4.1. Data Normalization at the Input Terminal

At the input terminal, GenAI initially executes a structural decoupling task on the text. The algorithmic model leverages Natural Language Processing (NLP) technologies to identify pedagogical entities within the lesson plan. As evidenced by Sorge et al. (2025) in utilizing large language models for educational analytics, specifying context and fine-tuning models on domain-specific corpora can fundamentally overcome the generic limitations of AI, thereby enabling individualized and context-specific diagnostic feedback for teachers' professional written outputs. Through this mechanism, the system transforms entity vocabulary, such as "four pencils" and "three pencil holders," into abstract mathematical variable parameters. Furthermore, the system translates "deriving a division formula" into a knowledge construction node. Affective modifiers concerning student interest and classroom atmosphere within the lesson plan are automatically filtered out by the algorithm, ensuring higher logical precision at the textual level.

4.2. Structured Prompting at the Diagnostic Terminal

Upon completion of data input, the system's core analysis relies on structured prompt engineering directives. LLMs require specialized directive design to be competent in specific pedagogical diagnostic tasks; hence, the diagnostic terminal employs programmatic directives in lieu of open-ended queries. Empirical studies demonstrate that programmatic directives possess pronounced advantages in diagnostic accuracy and logical clarity. To establish a highly reliable framework for structured prompting, this study cross-disciplinarily adapts the prompt taxonomy validated by Aruleba et al. (2026). Recognizing that instructional accuracy and ethical alignment are determinants of content quality in high-stakes environments, this taxonomy—predicated upon guided explanation, contextualised inquiry, and comparative reasoning (Aruleba et al., 2026)—is systematically contextualized within the current advanced LLM framework to govern the rigorous logical scanning of mathematics instructional texts. Concurrently, prompting scripts decompose the diagnostic process into specific cognitive steps, such as comprehending instructional intent, evaluating plan feasibility, and analyzing execution deviations (Malik et al., 2026). Such structured directives guide the AI to scan lesson plan texts layer by layer against pedagogical standards, ensuring that the diagnostic computations conform to rigorous disciplinary pedagogical logic.

4.3. Differentiated Feedback at the Output Terminal

Following the execution of diagnostic directives, the system generates revision feedback tailored to the specific lesson plan. To avert the provision of generalized theoretical expositions, the system must output individualized feedback endowed with high contextual adaptability (Sorge et al., 2025). However, the raw feedback generated by AI is susceptible to the limitations of rigidified cognitive levels and a lack of cultural sensitivity within complex pedagogical environments. Consequently, the output terminal must embed the HITL interactive review mechanism (Kamarulzaman, 2026). During the evaluation phase, teachers are responsible for conducting cognitive calibration on the preliminary diagnostic reports generated by the intelligent system, employing reflection-in-action strategies to instantaneously inspect and adjust the intelligent feedback (Dewi, 2025). Based on the teacher’s review outcomes, the system subsequently distills and outputs a differentiated, finalized lesson plan reorganization scheme. This synergistic closed-loop of machine generation and human verification helps ensure that the optimization recommendations tangibly align with the authentic demands of rural instruction.

5. Demonstration of the Pedagogical Reform Case and Trajectory Extrapolation

5.1. Standardized Processing of the Initial Lesson Plan

Using the purposively selected “Pigeonhole Principle” lesson plan, the initial step involves processing its original empirical recording method based on natural language narratives. This text contains numerous ambiguous descriptions, such as “magic trick introduction to stimulate interest” and “student group activities.” These descriptions conflate instructional steps with the teacher’s subjective emotions. Directly utilizing such texts for pedagogical evaluation is highly susceptible to generating evaluative bias.

At the input terminal, GenAI initially executes a structural decoupling task on the text. The algorithmic model leverages Natural Language Processing (NLP) technologies to identify pedagogical entities within the lesson plan. The system transforms entity vocabulary, such as “four pencils” and “three pencil holders,” into abstract mathematical variable parameters. Furthermore, the system translates “deriving a division formula” into a knowledge construction node. Affective modifiers concerning student interest and classroom atmosphere within the lesson plan are automatically filtered out by the algorithm.

The transformation process reorganizes the originally unstructured lesson plan into a data matrix comprising initial conditions, execution actions, and expected outputs. Original evaluation rubrics relied heavily on teachers' subjective visual observations. The algorithm transforms such subjective observations into extraction requirements for specific logical terminology. This data transformation mechanism thoroughly divests the affective empirical components inherent in traditional reflections. The transformed objective factual matrix establishes lucid algorithmic computational boundaries for subsequent logical diagnosis. To visually demonstrate this normalization process, Table 2 presents a detailed comparison between the experience-led raw textual form and the algorithmically extracted standardized data matrix.

Table 2

Comparison of Normalized Data Transformation at the Input Terminal of Instructional Design

Dimension of Transformation	Experience-Led Raw Textual Form	Standardized Data Matrix Extracted by Algorithm	Specific Function of the Transformational Mechanism
Objective Description	Experience the inquiry process and generate interest in learning mathematics.	Establish the inequality relationship between the number of items and containers and deduce its inevitability.	Translate subjective intentions into cognitive indicators measurable by algorithms.
Activity Sequence	Describe the teacher's magic trick introduction and students' group operations of placing pencils.	Map initial parameters and establish logical nodes for equal division actions and remainder processing.	Filter out classroom management actions and extract the pure backbone of pedagogical extrapolation.
Evaluation Indicators	The teacher evaluates whether students can keep up with the lesson flow based on subjective impressions.	Establish structured checkpoints targeting the "hypothesis method" and "model abstraction."	Transform fuzzy observations of classroom atmosphere into objective behavioral data acquisition.

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5.2. Algorithmic Diagnosis of Pedagogical Logic

Upon the generation of the data matrix, the system activates underlying logical rules to execute comparative computations. In the inquiry phase, the original lesson plan requires students to draw conclusions through the physical placement of four pencils into three pencil holders. Subsequently, the lesson plan directly presents a division formula with a remainder. The teacher's reflective records indicate that a subset of students exhibited delayed comprehension and unclear thinking when confronted with variant applications. Relying on experience, the teacher attributed the causes to the students' weak mathematical foundations or the inherent challenge of the problems themselves.

The artificial intelligence system identifies the fundamental flaw in this instructional sequence by comparing it against a cognitive progression model. The algorithm determines that limited physical operations can only demonstrate partial, incidental outcomes. Physical placement cannot exhaustively enumerate all possible distribution scenarios. Consequently, the system diagnoses that the lesson plan lacks the proof phase of the "Worst-Case Principle" during the leap from concrete operations to algebraic formulas.

The system further scans the content of the second-class session within the lesson plan. This session requires students to solve a problem involving the drawing of red and blue balls. The algorithm detects that the variable attributes of this task have changed. The "pigeonholes" in the prerequisite learning are concrete pencil holders, whereas the "pigeonholes" in the variant task are abstract colors. The system diagnoses that the original lesson plan fails to provide cognitive guidance for the transition from concrete entities to abstract attributes. The algorithmic extrapolation of the intelligent system has the potential to supersede the teacher's empirical guesswork.

The specific cognitive gaps identified during this phase, along with a dissection of the underlying logic contrasting the teacher's subjective attributions and the AI's structured diagnosis, are systematically outlined in Table 3.

Table 3

Comparison and Dissection of the Underlying Logic at the Diagnostic Terminal of Pedagogical Evaluation

Diagnostic Dimension	Teacher's Subjective Empirical Reflective Attribution	AI's Algorithmic Structured Diagnosis	Specific Function of the Diagnostic Mechanism
Locating Cognitive	Believes students cannot flexibly use	Diagnoses the absence of the "Worst-Case Principle" logical	Discovers an excessive leap in the

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Gaps	specific terminology such as "there always."	extrapolation physical manipulatives and the division model.	between instructional sequence through cognitive model comparison.
Variant Application Barriers	Notices students are at a loss when facing the red and blue ball variant problem.	Identifies a cognitive blind spot in the transition from color attributes to virtual pigeonholes.	Detects knowledge transfer failure caused by mismatched variable attributes between prior and subsequent tasks.
Direction of Intervention	Suggests increasing the volume of exercises and emphasizes students' spirit of independent exploration.	Points out the necessity of supplementing specific cognitive scaffolds for extreme distribution hypotheses and attribute mapping.	Transforms ineffective mechanical repetitive exercises into structural optimization targeting the logical gaps.

5.3. Structured Generation of the Improvement Plan

Based on the diagnostic results, the system outputs a specific pedagogical reorganization script. The reconstruction scheme completely alters the original inquiry trajectory. System directives require the teacher to abandon the practice of allowing students to randomly place pencils. Instead, the system provides a set of guiding scripts based on the "Worst-Case Principle." The script requires the teacher to constrain students' distribution actions, compelling them to execute an equal distribution first. After equal distribution, students discover the inevitable generation of a remainder. The secondary distribution of this remainder intuitively proves the mathematical inevitability of "at least two."

The reconstruction scheme introduces a digitized dynamic simulator. The system recommends that the teacher utilize the interactive whiteboard to demonstrate distribution scenarios with extremely large variables. Students input exceptionally large values for items and containers into the simulator, and the system algorithm instantaneously and exhaustively enumerates all distribution outcomes. This digitized demonstration breaches the quantitative constraints of physical manipulatives, enabling students to intuitively perceive the universality of mathematical laws under massive data conditions.

Addressing the red and blue ball variant task, the system outputs an attribute mapping tool table. This tool table compels students to define virtual pigeonholes prior to problem-solving. Students are required to explicitly input the two abstract colors, red and blue, into the concrete container list. Furthermore, the original three-tier subjective evaluation rubric is discarded by the system and upgraded into a process-oriented logical checklist. The teacher no longer focuses solely on the correctness of the final answer; instead, relying on the checklist, the teacher verifies in real-time whether students have executed the equal distribution and color mapping actions. This reconstruction scheme is designed to facilitate a substantive leap from empirical operations to rigorous mathematical logical reasoning.

To further illustrate the efficacy of this pedagogical upgrading, Table 4 provides a comprehensive comparison of the practical operational phases between the original empirical instruction and the intelligent-assisted logical reorganization.

Table 4

Comparison of Practical Scheme Reconstruction at the Output Terminal of Instructional Design

Practical Operational Phase	Superficial Empirical Instruction of the Original Lesson Plan	Deep Logical Instruction of the Intelligent-Assisted Reorganization	Specific Efficacy of Pedagogical Upgrading
Principle Deduction	Students freely attempt to place pencils and passively accept the division formula.	Mandatorily execute equal distribution and process the remainder according to the script to complete the logical proof.	Remediate logical loopholes, enabling students to genuinely comprehend the rigor of mathematical deduction.
Tool Application	Rely solely on a small quantity of physical pencils and paper cups for physical operations.	Introduce a large-parameter dynamic simulator to instantaneously demonstrate the inevitable distribution outcomes of massive data.	Breach physical constraints, establishing the universal concept of mathematical models under extreme data.
Variant Transfer	The teacher verbally informs students of the backward reasoning method, requiring abstract mental speculation.	Utilize an attribute mapping tool table to translate abstract color characteristics into concrete virtual containers.	Provide concrete cognitive scaffolds, clearing the barriers from physical distribution to abstract modeling.
Outcome Assessment	The teacher provides subjective grading post-class based on the	Utilize an in-class logical checklist to real-time verify the execution of key	Discard summative scoring, achieving precise tracking and

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	accuracy rate practice exercises.	ofdeductive steps.	instantaneous rectification of the cognitive process.

6. Implementation Safeguards and Subjectivity Risk Prevention

6.1. Data Protection and Trust Repair Mechanisms

The normalized operation of the intelligent diagnostic system is highly contingent upon the authentic pedagogical data submitted by rural teachers. However, the cloud-based processing of massive volumes of lesson plans, reflective logs, and classroom interaction records presents unprecedented challenges to privacy protection within the educational sphere. While utilizing intelligent tools to enhance instructional quality, rural teachers pervasively harbor apprehensions regarding data ownership, storage security, and algorithmic black boxes. This “privacy paradox” significantly constrains the deep application of the technology, resulting in a phenomenon where teachers desire precise intelligent diagnostic feedback while simultaneously experiencing acute anxiety that their personal pedagogical experiences might be disorderly scraped by algorithms or utilized for unauthorized analysis.

Establishing a robust human-machine trust system must advance synchronously from two dimensions: technological encryption and the clarification of ownership rights. The foundational architecture of the system must mandatorily embed high-level data desensitization mechanisms, ensuring that all uploaded raw instructional records undergo anonymized extraction. This achieves the physical isolation of sensitive personal information from objective pedagogical facts during the computational phase. Concurrently, the AI platform must establish lucid boundaries for data usage, explicitly stipulating the intellectual property ownership principles of pedagogical resources post-diagnosis. This security safeguard mechanism can effectively alleviate teachers’ privacy anxiety and serves as the core prerequisite for ensuring the sustainable operation of the intelligent teaching and research system (Al-Abdullatif, 2024).

Furthermore, the degree of standardization in data governance directly determines teachers’ trust and willingness to adopt Generative AI (Saputra et al., 2025). Therefore, administrative departments must ensure teachers possess absolute control over their digital pedagogical assets by establishing transparent informed consent and data withdrawal permissions. Only under the premise of safety and controllability can teachers confidently integrate intelligent diagnosis into their daily teaching and research routines. The establishment of this trust relationship is not an overnight endeavor; it requires the gradual elimination of the fear induced by technological alienation through long-term demonstrations of algorithmic transparency and data compliance reviews, thereby laying a solid ethical foundation for the digital transformation of rural education.

6.2. Algorithmic Dependency Avoidance and Agency Maintenance Strategies

The widespread popularization of GenAI-assisted instructional design, while significantly reducing workload intensity, simultaneously induces a severe risk of algorithmic dependency. Because the ultimate objective of technological empowerment is to elevate teachers' professional competencies rather than enact wholesale technological substitution, unconstrained intelligent assistance may lead teachers to gradually lose the cognitive friction necessary for independent instructional design. When teachers become habituated to directly adopting algorithmically generated lesson plan texts, the depth and originality of individual pedagogical reflection will be severely undermined. Teachers may degenerate into mechanical executors of algorithmic directives, ultimately precipitating the disembedding and atrophy of rural teachers' professional capabilities.

To prevent technological alienation, the interactive bottom line of the HITL paradigm must be steadfastly maintained throughout the system's operational workflow (Kamarulzaman, 2026). The intelligent diagnostic system should be delineated as a cognitive scaffold rather than the sole endpoint of decision-making. Consequently, the system workflow must mandatorily require teachers to conduct substantive secondary reviews of the AI-outputted optimization schemes, executing localized contextualization of the algorithmic recommendations based on specific rural learning conditions. This human-machine synergistic interventional process maintains the requisite cognitive engagement, ensuring that machine logic perpetually serves human educational intent, thereby safeguarding the teacher's core status within the technology-assisted environment.

The essence of the human-machine collaborative workflow lies in the re-establishment of the pedagogical subject's professional dignity (Balraj, 2025). Machines should undertake foundational structural scanning, data extrapolation, and routine content generation tasks. Conversely, teachers should focus their professional energies on higher-order educational dimensions, such as cultural adaptive modifications, emotional value injection, and complex learning condition assessments. Through this functional division of labor, AI transforms into a lever that amplifies teachers' professional wisdom. This return of subjectivity not only effectively circumvents the risk of deskilling induced by homogenized instruction but also guarantees the continuous evolution of rural teachers amidst technological paradigm shifts.

6.3. Institutional Reform and Ecological Reconstruction Pathways

The at-scale implementation of Generative AI within the rural educational system necessitates the support of a complementary institutional empowerment framework. Because traditional educational management architectures frequently lack scientific evaluation criteria tailored for the integration of intelligent technologies, the singular introduction of hardware and software can no longer fundamentally alter the teaching and research ecology of rural schools. Therefore, school administration must construct an environment that supports the continuous development of the AI-TPACK framework, deeply integrating technological literacy into professional title evaluations, performance appraisals, and professional training systems. This institutional-level reform safeguards the transition of the intelligent diagnostic system from the experimental phase to normalized application.

In specific implementation, the teaching and research evaluation system must pivot from result-oriented textual assessments toward process-oriented assessments emphasizing technological integration. Administrative departments should establish specialized incentive mechanisms targeting AI-assisted pedagogical reform, encouraging teachers to conduct bold pedagogical experiments utilizing intelligent tools. Furthermore, the compliant application capabilities of prompt engineering and techno-ethical norms should be formally incorporated into teachers' professional development assessment indicators (Aruleba et al., 2026). Concurrently, institutions must provide teachers with a safe pedagogical trial-and-error space, permitting multiple iterations during the process of lesson plan reconstruction via intelligent diagnosis. This transformation in evaluation culture will immensely boost rural teachers' proactiveness in embracing nascent technologies.

Moreover, administrative departments should ensure teachers accurately master the logic of communicating with algorithms by providing structured prompt engineering training, thereby fundamentally elevating the intellectualization of rural teaching and research. By establishing a multi-stakeholder collaborative governance mechanism, educational experts, technology developers, and rural teachers can jointly participate in the revision and refinement of diagnostic logic. This comprehensive safeguard system will ultimately establish a sustainably developing intelligent pedagogical ecology. The deep structural coupling of technological tools and management institutions will not only resolve current pedagogical pain points but, through long-term institutional constraints, ensure that AI technologies perpetually serve the grand objective of educational equity and high-quality development in rural education.

7. Conclusion

7.1. Summary of Core Findings and Paradigm Evolution

This study explores the specific pathways of GenAI-assisted pedagogical reform for rural teachers. The research seeks to elucidate the intrinsic mechanism of transitioning pedagogical diagnosis from empirical reflection toward an intelligence-driven paradigm. GenAI exerts a crucial digital scaffolding role in optimizing instructional design. The study constructs an intelligent assistance system encompassing input terminal normalization, diagnostic terminal structuration, and output terminal differentiation. This system transforms teachers' fragmented pedagogical experiences into quantifiable, standardized data. This transformation is hypothesized to bridge the cognitive gaps experienced by rural teachers due to a scarcity of professional support.

Empirical extrapolation further illustrates the theoretical interventional efficacy of the intelligent diagnostic system. The intelligent system is hypothesized to be capable of systematically scanning instructional sequences and identifying deep logical blind spots. In the pedagogical reconstruction of abstract mathematical concepts, AI-assisted methodologies are expected to significantly enhance the rigor of instructional design. Through digital simulation, the system fills the logical proof vacuum left by traditional physical manipulatives. This paradigm evolution aims to optimize lesson plan structures and reshape teachers' professional cognitive mindsets. Pedagogical practice shifts from unidirectional knowledge indoctrination to deep interaction based on logical deduction. It is anticipated that a new normalcy of data-driven instructional improvement can be thereby established.

7.2. Elucidation of Theoretical Contributions and Practical Value

In the theoretical dimension, this study expands the application boundaries of the Artificial Intelligence Technological Pedagogical Content Knowledge (AI-TPACK) framework within the rural educational sphere. By introducing core perspectives such as digital scaffolding and the "Human-in-the-Loop" (HITL) paradigm, the research redefines the role positioning of rural pedagogical subjects in the age of intelligence. The intelligent diagnostic system represents not merely an innovation in technological tools, but more fundamentally, a systemic upgrade of cognitive management mechanisms. This mechanism elucidates the intrinsic logic of intelligent intervention in reorganizing instructional design. This exploration provides an operational evaluation benchmark for subsequent educational technology research.

In the practical dimension, this study provides a viable blueprint for dismantling the bottlenecks impeding the enhancement of rural educational quality. The normalized application of the intelligent diagnostic system enables rural teachers to transcend spatiotemporal constraints to acquire high-quality professional feedback. The differentiated diagnosis outputted by the system satisfies the phasic developmental needs of teachers across varying literacy levels. The precise professional empowerment mechanism effectively mitigates the structural imbalance of urban-rural teaching and research resources. The successful evolution of the pedagogical reform case substantiates the substantive enhancement of rural classroom efficacy facilitated by AI. The research findings contribute a concrete practical paradigm for advancing the high-quality development of rural education.

7.3. Limitations and Future Research Directions

Although this study has preliminarily constructed an intelligent diagnostic system and validated its application efficacy conceptually, limitations persist regarding the disciplinary coverage of the research sample and the lack of empirical data. Specifically, three primary limitations must be addressed. First, practical disparities in hardware and internet infrastructure among rural schools pose significant non-technological constraints on the comprehensive popularization of the diagnostic system. Second, the system faces the inherent risk of algorithmic hallucinations or erroneous AI diagnoses; if deployed without rigorous human oversight, flawed AI feedback could negatively impact classroom practice and misguide students' conceptual development. Third, while the "Human-in-the-Loop" paradigm is proposed, the long-term effects of AI dependency remain a critical concern, potentially eroding teachers' professional autonomy and altering their pedagogical identity over time. Future research should expand the coverage of empirical samples (incorporating classroom observations and interview data) and explore the establishment of an interdisciplinary, universal diagnostic logic to enhance the generalizability of intelligent assisted methodologies.

Subsequent research should focus predominantly on the construction pathways of a long-acting intelligent teaching and research ecology. The iteration of artificial intelligence algorithms requires closer alignment with the localized characteristics of rural education. Algorithmic models should deeply mine the unstructured tacit knowledge of teachers within authentic pedagogical contexts. Educational administration departments must continuously optimize institutional safeguard systems, preventing the risks of technological alienation and algorithmic dependency through multi-stakeholder collaborative governance models. Commensurate with the continuous evolution of Generative AI technologies, intelligent diagnostic systems are bound to progressively transition toward high-level adaptivity and deep anthropomorphism. This continuous, system-level optimization will ultimately realize the educational vision of deep human-machine synergy. Intelligent technologies will emerge as the core driving force propelling the systemic transformation of rural education.

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Data Availability

No datasets were generated or analysed during the current study.

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The authors declare that there is no Conflict of interest.

Ethics approval

Not applicable.

Consent to participate

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Consent for publication

All authors have given their consent.

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