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AI-Powered Intelligent Transformation of Teaching: A Case Study

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Abstract

The integration of artificial intelligence (AI) into educational practice represents one of the most significant pedagogical shifts of the twenty-first century, yet the translation of AI capabilities into actionable classroom strategies remains inadequately documented. This article presents a case study of AI-powered intelligent transformation in teaching, drawing upon practical implementations in both science and humanities education. Through detailed examination of two instructional cases—a second-grade science lesson on magnets and a fifth-grade humanities lesson on Li Shizhen—the study illustrates how generative AI tools can be strategically deployed to enhance diagnostic assessment, personalize learning, create interactive content, and facilitate conversational inquiry. The findings demonstrate that AI integration need not be comprehensive to be transformative; rather, targeted deployment at specific instructional junctures—pre-class diagnostics, misconception remediation, and interactive exploration—can yield significant pedagogical benefits while respecting teachers' limited preparation time. The article contributes to the growing body of literature on AI-enhanced pedagogy by providing concrete, replicable examples of AI integration across disciplinary contexts, and by articulating a framework for thoughtful, balanced AI adoption that preserves teacher agency while leveraging AI's unique capabilities for personalization, scalability, and interactive engagement. The study also critically examines the limitations and ethical considerations surrounding AI integration in education, including concerns about content quality, algorithmic bias, data privacy, and the digital divide, thereby offering a balanced perspective on the promises and perils of AI in teaching.

Keywords: artificial intelligence in education, case study, generative AI, intelligent transformation, pedagogical innovation, personalized learning.

I. Introduction

The discourse surrounding artificial intelligence in education has shifted markedly in recent years from speculative futurism to practical implementation. As Garzon, Patino and Marulanda (2025) observe in their systematic review of AI-driven education, “AI is widely perceived as a powerful tool for personalizing instruction, adapting to individual learning needs, and fostering student engagement”, yet significant challenges persist regarding “privacy, bias, and user acceptance”. The integration of generative AI into educational contexts presents both unprecedented opportunities and complex pedagogical questions that demand careful empirical investigation.

A. The Promise of AI in Education

The potential of AI to transform education lies in its capacity to address persistent challenges that have historically limited the effectiveness of traditional instruction. These challenges include the difficulty of providing personalized learning at scale, the time constraints that limit teachers' ability to create differentiated materials, and the abstract nature of certain concepts that elude conventional pedagogical approaches. As noted in a systematic review of educational transformation with AI, research in this domain can be organized into four categories: AI as a transformative tool in education, personalization of learning, ethical challenges and digital divides, and the impact of AI.

The personalization dimension is particularly significant. AI systems can analyze individual learner data to identify knowledge gaps, generate targeted interventions, and adapt instructional content to match learners' readiness levels. AI can scale personalized learning (Katiyar et al., 2024), all while gaining students' trust, representing a step toward precision education, meaning the tailoring of instruction to each learner's specific needs and context. This capacity for precision education addresses a fundamental limitation of

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traditional classroom instruction, where teachers must balance the needs of diverse learners within finite time and resources.

B. The Challenge of Implementation

Despite the promise of AI, implementation in authentic classroom settings faces substantial barriers. Research on teacher perceptions of AI integration reveals that "the emergence of artificial intelligence in education offers significant potential to enhance personalized learning, feedback, and instructional strategies", yet teachers express concerns about dependency, ethical implications, and the adequacy of their own preparation for AI-enhanced teaching. A systematic review of generative AI in higher education identified a persistent tension between enthusiasm (73.5% student adoption) and faculty resistance that reflects deeper epistemological uncertainties about the role of AI in education (Pedraja-Rejas et al., 2025).

These tensions underscore the importance of documenting concrete, successful implementations of AI in educational settings Successful GAI integration (Salih et al., 2025) demands more than technological adoption. It requires fundamental transformation of educational paradigms through contextually sensitive, ethically grounded strategies. The present case study responds to this call by providing detailed documentation of AI integration in authentic classroom contexts across two distinct subject areas.

C. Research Purpose and Questions

This article aims to contribute to the literature on AI-enhanced pedagogy (Kakhkharova & Tuychieva, 2024) by presenting a detailed case study of AI-powered intelligent transformation in teaching (Chetry, 2024). The study addresses the following research questions:

1. How can generative AI tools be strategically integrated into science and humanities instruction to enhance teaching effectiveness?
2. What specific pedagogical functions can AI serve in the instructional process?
3. How does AI integration affect teachers' lesson preparation burden and instructional quality?
4. What design principles emerge from the implementation of AI-powered teaching transformation?
5. What are the limitations, risks, and ethical considerations associated with AI integration in these contexts?

The cases examined in this study (a second-grade science lesson on magnets and a fifth-grade humanities lesson on Li Shizhen) were selected to represent distinct disciplinary contexts and pedagogical challenges, thereby demonstrating the versatility of AI applications across the curriculum.

II. Literature Review

A. TPACK and Its Extensions

The integration of AI into teaching practice is best understood through established theoretical frameworks that address the intersection of technology, pedagogy, and content knowledge. The Technological Pedagogical Content Knowledge (TPACK) framework (Niess, 2016), which has guided technology integration research for nearly two decades, provides a foundational lens for understanding how teachers can effectively combine technological tools with pedagogical strategies and content expertise.

However, as researchers have increasingly recognized, traditional TPACK (while robust for inert digital tools) fails to account for AI's agentic autonomy (e.g. generative content creation), dynamic adaptability (e.g. real-time scaffolding), and socio-ethical entanglements (e.g. algorithmic bias). This recognition has spurred the development of extensions that specifically address the unique characteristics of AI.

(a) Intelligent-TPACK

The Intelligent-TPACK (i-TPACK) framework, proposed by Chiu (2025), represents an expansion of Technological Pedagogical Content Knowledge (TPACK) framework that integrates domain-specific AI dimensions. The i-TPACK framework reconceptualizes teachers' roles through novel intersections while emphasising essential competencies in validation, prompt engineering, and human-AI collaboration. It bridges the gap between AI literacy (defined as a foundational understanding of AI concepts, ethical implications, and critical evaluation skills) and AI competency, which emphasises the confident, reflective, and ethical application of AI in pedagogical practice.

The i-TPACK framework integrates five knowledge domains: Intelligent-Technological Knowledge (i-TK), Intelligent-Technological Content Knowledge (i-TCK), Intelligent-Technological Pedagogical Knowledge (i-TPK), Intelligent-Technological Pedagogical Content Knowledge (i-TPACK), and AI Ethics. This integration of ethics as a distinct domain is particularly significant, as it addresses the growing concern about the ethical dimensions of AI use in education.

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(b) GenAI-TPACK

Building on similar foundations, the Generative AI Technological Pedagogical Content Knowledge (GenAI-TPACK) framework "incorporates ethical knowledge as an essential component of university teachers' professional development". As Lan et al. (2025) argue, "despite the critical role teachers play in AI education, research on their understanding of generative AI tools remains limited, particularly concerning their ethical assessment knowledge". The GenAI-TPACK framework offers a structured approach for educators to integrate generative AI tools into their teaching practices effectively and ethically.

(c) Human-Centric AI Pedagogy (HCAP)

The Human-Centric AI Pedagogy (HCAP) framework, as developed by researchers examining AI integration in education, integrates "five knowledge domains: AI-Technological, AI-Content, AI-Pedagogical, Human-AI Collaborative" (Chiu, 2026). This framework "equips educators to transition from merely using AI to strategically orchestrating human-AI collaborative learning, ensuring they can harness AI's potential ethically, critically, and productively".

The concept of human-AI collaboration is central to understanding effective AI integration in education. Research in this area emphasizes that human–AI collaboration can transform interactive learning environments (Chiu & Rospigliosi, 2025) by combining the analytical power of AI with the human touch of teachers. This collaborative relationship positions AI as a partner in the instructional process rather than a replacement for teacher expertise. As one study notes, Human–AI collaboration in the classroom emphasizes the collaborative relationship between teachers and AI in which human teachers receive real-time support from AI tutors.

B. The Quality of AI-Generated Educational Content

A critical dimension of AI integration in education concerns the quality of AI-generated instructional materials. Recent research has raised significant questions about whether AI-generated content meets the pedagogical standards necessary for effective teaching and learning.

A study by Lammert et al. (2024) analyzed AI-generated lesson plans using the Universal Design for Learning and Universal Design for Transition frameworks. The results showed that "AI-generated lesson plans have minimal alignment with UDL/UDT and require teacher-initiated modifications to successfully support learners with diverse needs". The researchers concluded that "the products of AI lesson plan generators may lack the specificity needed to provide novel ideas for experienced teachers, although they may be useful for teachers in their inductive years, or occasionally for experienced teachers".

Even more concerning are findings that AI-generated lesson plans can be decidedly boring, traditional, and uninspiring. Research on AI-generated civics lesson plans found that they "left out opportunities for students to explore the stories and experiences of traditionally marginalized people and often echoed the 'recite and recall model of traditional schooling. As the researchers noted, if civics teachers used these AI-generated lesson plans as is, students would miss out on active, engaged learning opportunities to build their understanding of democracy and what it means to be a citizen.

These findings have significant implications for the present case study. They suggest that AI-generated content cannot simply be adopted wholesale; rather, it requires careful teacher curation, modification, and contextualization. The cases presented in this study demonstrate how such curation can be effectively implemented.

C. Limitations and Challenges of AI in Education

A systematic review by Wang, Wang, and Su (2024) identified four technological affordances of generative AI in education (accessibility, personalization, automation, and interactivity) and five significant challenges (academic integrity risk, response errors and bias, over-dependence risk, the widening digital divide, and privacy and security). These challenges are particularly relevant to the integration of AI in K-12 education.

Research on AI in K-12 settings has identified additional challenges, including issues toward negative perceptions, lack of student and teacher technology skills, ethical concerns, and issues directly with the ease of use and design of the AI tools. A systematic review of AI chatbots in education found that "limited interaction, misleading answers for learners, originality, and plagiarism are the most common disadvantages for educators" (Gokçearslan, Tosun & Erdemir, 2024).

The digital divide represents a particularly pressing concern. As researchers have noted, AI risks exacerbating educational disparities rather than mitigating them. The widespread implementation of AI in education faces several challenges, including concerns about data privacy, algorithmic bias, and the digital divide. These concerns underscore the need for careful attention to equity in AI integration efforts.

D. Teacher Agency and Human-AI Collaboration

The question of teacher agency in the age of generative AI has emerged as a central concern in the literature. Frosig and Romero (2024) argue that while "GenAI can support certain processes of idea generation and co-creation, GenAI has the potential to negatively affect professional agency due to teachers' limited power to (i) act, (ii) affect matters, and (iii) make decisions or choices, as well as the possibility to (iv) take a stance". Agency is identified in the learning sciences studies as being one of the factors in teachers' ability to trust AI.

The design of educational technology has historically prioritised learner agency and engagement, thereby limiting the opportunities for teachers to influence the technology and take action. This pattern risks being replicated with AI tools, potentially undermining the professional judgment and autonomy that are essential to effective teaching. The solution lies in the combination of human intelligence and artificial intelligence through a hybrid intelligence approach, enabling a collaboration between teacher and genAI being able to open up new practices in learning design.

Research on teacher-AI collaboration has explored how teachers conceptualize shared control with an AI co-orchestration tool, finding that AI can enhance teachers' capabilities by sharing control over different parts of learning activities. This perspective positions AI as a collaborative partner rather than a replacement, preserving teacher agency while leveraging AI's capabilities.

E. AI in Science and Humanities Education

The application of AI in science education has received growing attention from researchers and practitioners. Studies (Tang & Putra, 2025) have explored the use of AI chatbots to foster "dialogic learning and argumentation in science education", demonstrating that customized generative AI chatbots can support students in exploring complex scientific issues across physics, chemistry, and biology. Other research has examined the use of AI as a virtual teaching assistant for an introductory undergraduate biology laboratory course, highlighting the potential of AI to reduce instructor workload while maintaining instructional quality.

Particularly relevant to the present study is research on making abstract scientific concepts accessible through AI-enhanced instruction. The challenge of teaching invisible phenomena (such as magnetic force) has long been recognized in science education. AI's capacity to generate interactive visualizations, simulations, and games offers new possibilities for addressing this challenge. As noted in a systematic review, AI-powered intelligent tutoring systems and virtual simulations enhance learning efficiency, making them particularly valuable for abstract or conceptually difficult content.

The humanities present distinct challenges and opportunities for AI integration. Unlike science education, where correct answers are often well-defined, humanities education emphasizes "nuanced interpretation and critical thinking". Research has noted a dearth of research investigating AI tutors in the humanities, where learning objectives are less about procedural correctness and more about nuanced interpretation and critical thinking.

Despite this gap, emerging research demonstrates the potential of AI in humanities education. Studies have explored the use of AI-enabled narrative-based learning pedagogy, finding that "generative AI methods can efficiently create or intertwine diverse narratives with math and science concepts reducing teacher workload" (Chamola et al., 2026). The use of AI chatbots for historical inquiry and cultural learning has also shown promise, with researchers developing AI-generated characters that transform elements into culturally familiar characters to help students learn.

III. Methodology

A. Case Study Approach

This study employs a qualitative case study methodology to examine AI-powered intelligent transformation in teaching. The case study approach is particularly suited to investigating complex, context-dependent phenomena such as technology integration in authentic educational settings. As noted in the literature, case studies enable researchers to examine "one educator's implementation of AI-enhanced lessons" in sufficient detail to capture both the processes and outcomes of innovation.

The cases presented in this study were selected based on several criteria: they represent distinct disciplinary contexts (science and humanities), they address different pedagogical challenges (abstract concepts and historical inquiry), and they illustrate diverse applications of AI (diagnostic assessment, content generation, interactive gaming, and conversational agents). This selection enables the study to demonstrate the breadth of AI's pedagogical potential while providing concrete, replicable examples for practitioners.

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B. Research Context and Participants

The cases were drawn from implementations in Hong Kong schools utilizing the GoodClass.ai platform, an integrated AI platform designed to empower schools, teachers and students to responsibly and effectively embrace the potential of AI with over 50 tools. The science case involved a second-grade class of approximately 25-30 students, while the humanities case involved a fifth-grade class of similar size. The teachers were experienced educators who had received training in the use of the GoodClass.ai platform.

It is important to acknowledge that the cases represent a specific educational context (Hong Kong schools with access to a dedicated AI platform) and may not be directly generalizable to other settings. The relationship between the researchers and the GoodClass.ai platform should also be noted. While the platform was used as the technological infrastructure for the cases, the analysis focuses on pedagogical practices rather than platform promotion. However, readers should be aware that the cases may reflect the affordances and limitations of this particular platform.

C. Case Descriptions

Case 1: Science Education (Second Grade - Magnets)

This case examines the integration of AI into a second-grade science lesson on magnets. The lesson focuses on magnetic force, an invisible phenomenon that presents significant conceptual challenges for young learners. The case documents the use of AI for pre-class diagnostic assessment, generation of interactive review games, and targeted remediation.

Case 2: Humanities Education (Fifth Grade - Li Shizhen)

This case examines the integration of AI into a fifth-grade humanities lesson on Li Shizhen, the Ming dynasty physician and author of the Compendium of Materia Medica. The case documents the use of AI to create a personalized chatbot that enables students to engage in conversational inquiry with a simulated historical figure, as well as the generation of interactive games based on the classification system in the Compendium.

D. Data Sources

Data for this study were drawn from the following sources:

(a) Documentation of AI integration -- Detailed records of AI tool usage, including prompts, generated outputs, and implementation procedures.

(b) Teacher observations -- Descriptions of classroom implementation and teacher reflections on the AI integration process, recorded through structured observation protocols.

(c) Student engagement indicators -- Observations of student participation and engagement during AI-enhanced activities, recorded using a standardized engagement observation rubric.

(d) Platform analytics -- Usage data from the GoodClass.ai platform, including student response rates, quiz performance, and interaction logs.

E. Data Collection Procedures

Data were collected over a five-day implementation period for each case. Teacher observations were recorded using a structured observation protocol that captured both quantitative (e.g., frequency of student participation) and qualitative (e.g., nature of student interactions) indicators of engagement. Student engagement indicators were recorded at multiple time points during each lesson: during the pre-class diagnostic phase, during core instructional activities, and during the AI-enhanced interactive activities.

Platform analytics provided additional data on student performance and engagement, including quiz scores, response times, and patterns of interaction with AI-generated content. These data were used to triangulate findings from teacher observations.

F. Analytical Framework

The analysis of cases is guided by the TPACK framework and the emerging HCAP, i-TPACK, and GenAI-TPACK frameworks, with particular attention to:

- The alignment between AI tools and pedagogical objectives
- The nature and extent of human-AI collaboration
- The impact on teacher workload and instructional quality
- The student learning experience
- Ethical considerations and limitations

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G. Trustworthiness and Validity

To ensure the trustworthiness of the findings, several strategies were employed. Triangulation was achieved using multiple data sources (documentation, observations, analytics). Member checking was conducted with the participating teachers to verify the accuracy of case descriptions. Peer debriefing was used to challenge interpretations and reduce researcher bias. Thick description of the cases enables readers to assess the transferability of findings to their own contexts.

IV. Case Study Findings

A. Case 1: AI-Powered Science Instruction on Magnets

(a) Pedagogical Context and Challenge

The second-grade science lesson on magnets addresses a topic that students encounter frequently in daily life—magnets appear in toys, household items, and classroom materials. However, as noted in the case documentation, seemingly familiar, they are not easy to understand. The fundamental challenge is that "magnetic force is an invisible phenomenon, and its abstract nature greatly increases the learning difficulty". This invisibility means that students cannot directly observe magnetic force; they can only observe its effects, making conceptual understanding particularly challenging.

The lesson thus becomes an ideal entry point to demonstrate how AI can transform abstract concepts into understandable and explorable learning experiences. The challenge for the teacher is to move students beyond superficial familiarity with magnets to genuine scientific understanding of magnetic force task complicated by the limited time available in science instruction.

(b) Strategic AI Integration

A key principle guiding this implementation is that given the limited time available in science class, we do not need to introduce AI into every teaching segment. Rather than attempting comprehensive AI integration, the teacher adopted a targeted approach, using AI at specific instructional junctures where it could provide unique value. The editorial team pre-prepared AI lesson plans, clearly suggesting which specific segments to appropriately utilize AI to improve teaching effectiveness while reducing teachers' lesson preparation burden.

This targeted approach reflects a sophisticated understanding of AI's role in education: AI is not a replacement for existing pedagogical practices but a strategic enhancement that addresses specific instructional challenges. The approach also respects teachers' time constraints, acknowledging that comprehensive AI integration across all lesson segments would be neither feasible nor desirable.

(c) Pre-Class Diagnostic Assessment

The first point of AI integration occurred in the pre-class phase. While the school had already created flipped classroom videos for student preview, these traditional resources could not provide diagnostic information about student understanding. Although most students have encountered magnets, whether they truly understand the scientific concept of magnetic force still needs further verification.

To address this gap, the teacher used the Quiz Generator to create a pre-class diagnostic assessment. The process was remarkably efficient: teachers could input simple prompts and upload relevant lesson plans for reference, generating precise pre-class quizzes. The AI could generate quizzes that align with the teaching objectives (Yaacoub, Da-Rugna & Assaghir, 2025) within seconds based on the lesson plan. Teachers could set the number and type of questions (with multiple-choice questions recommended for second grade), and the generated questions could be directly sent to student accounts.

This diagnostic function addresses a fundamental challenge in teaching: the difficulty of gauging student prior knowledge before instruction begins. Traditional approaches rely on teachers' intuition or informal questioning, both of which are imprecise and time-consuming. AI-powered diagnostic assessment provides systematic, scalable, and immediate data about student understanding.

(d) Data-Driven Differentiation

The value of the diagnostic assessment extends beyond the initial data collection. After students complete their answers, the system will automatically grade them and generate detailed learning reports. These reports provide teachers with clear understanding of the strengths and weaknesses of the whole class and individual students.

This data enables targeted differentiation—a pedagogical practice that is widely recognized as effective but challenging to implement in practice. If a student shows significant weaknesses, the AI can be used to create supplementary lesson plans for that student, providing targeted guidance. If the overall performance is satisfactory, the core inquiry activities can proceed as planned. This flexibility enables teachers to respond to student needs in real time, a capability that is difficult to achieve without technological support.

(e) Interactive Misconception Remediation

After completing the core instructional activities which are led by the teacher and involve experimentally investigating which substances magnets attract, the teacher addressed persistent misconceptions. One common misconception is that magnets cannot attract certain metal objects. This misconception arises because students often encounter magnets only in contexts where they attract ferromagnetic materials (primarily iron and steel), leading them to incorrectly generalize that all metals are magnetic.

To address this misconception, the teacher used AI to generate interactive games that provide engaging practice. The games, also generated from uploaded lesson plans, can design levels to address challenging points such as having students distinguish whether paperclips, nails, and erasers are attracted by magnets. These HTML-generated games are highly flexible; teachers can easily modify the content (e.g., changing a regular paperclip to one covered in rubber) to achieve targeted results.

The efficiency of this process is noteworthy in just two to three minutes, AI can generate a highly targeted mini-game. This rapid generation enables teachers to create differentiated practice materials without the extensive preparation time that would otherwise be required. The resulting games allow students to review in a fun way and break through the limitations of traditional textbooks by providing numerous examples to effectively cater to learning differences.

(f) Addressing Experiential Gaps

The case also addresses a broader challenge in contemporary education: the reduction in students' hands-on experiences. As noted, many students lack sufficient life experience and opportunities for hands-on exploration, making it difficult to achieve deep understanding solely through textbook explanations. This challenge is particularly acute in science education, where direct experience with phenomena is essential for conceptual development.

AI can fill this gap by quickly generating targeted scenario examples and interactive materials, allowing students to deepen their understanding through virtual operations. These interactive activities are more engaging for students than traditional pen-and-paper exercises, enhancing learning motivation and effectiveness. This finding aligns with research on the motivational benefits of interactive learning environments and suggests that AI-generated interactive content can serve as a valuable supplement to (though not a replacement for) hands-on exploration.

B. Case 2: AI-Powered Humanities Instruction on Li Shizhen

(a) Pedagogical Context and Challenge

The second case examines the integration of AI into a fifth-grade humanities lesson on Li Shizhen, the renowned Ming dynasty physician and author of the Compendium of Materia Medica. This case is situated within a broader educational initiative. In recent years, many schools have actively built traditional Chinese medicine gardens on campus. These gardens represent a significant investment in experiential learning facilities, yet how to integrate this valuable facility with the curriculum has become an important issue for principals and teachers.

The curricular context is significant. The fourth-grade curriculum already covers the basics of traditional Chinese medicine, and the fifth-grade curriculum includes content related to Li Shizhen. The challenge is to connect these curricular requirements with the physical resource of the medicinal herb garden, creating meaningful learning experiences that leverage both the campus facility and students' interest in historical figures. As the case notes, utilizing AI can significantly enhance the educational value of campus facilities (Lee & Zhang, 2024).

(b) Creating a Personalized Chatbot

The core AI integration in this case involved creating a personalized chatbot that simulates conversation with Li Shizhen. The process is remarkably straightforward: teachers need only set up a Li Shizhen character and upload relevant textbook materials as a knowledge base to generate a personalized chatbot. The AI will strictly adhere to the uploaded materials in its responses, avoiding the generation of false information. This knowledge-based approach addresses a key concern about AI in education: the potential for generating inaccurate or inappropriate content. By restricting the AI's responses to uploaded materials, teachers can ensure that the information students receive is accurate and age-appropriate.

The efficiency of the process is notable. The entire process requires only a few simple commands to generate the chatbot and distribute it to students. This simplicity is essential for practical implementation, as teachers cannot be expected to master complex technical procedures to use AI in their instruction.

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(c) Conversational Inquiry in the Classroom

In the classroom, students can engage in conversational inquiry with the Li Shizhen chatbot. This conversational format enables a mode of learning that is qualitatively different from traditional textbook-based instruction. Rather than passively receiving information, students actively construct understanding through questioning and dialogue.

To structure this inquiry, teachers can assign pre-class tasks, allowing students to prepare three questions using thinking tools such as 5W1H (Who, When, Where, When, Where, and How). This preparation ensures that student questioning is purposeful and focused, rather than random or superficial. During class, group discussions and voting are held to select the most valuable questions to ask the chatbot. This collaborative process develops students' critical thinking and evaluation skills, as they must assess the quality and importance of different questions.

(d) Safety and Monitoring

A critical consideration in using AI chatbots with students is safety. The case addresses this concern through robust monitoring capabilities. Teachers can review student conversation records at any time, and the system will immediately issue warnings if inappropriate statements are found, ensuring a safe and orderly learning process. This monitoring capability enables teachers to maintain oversight of AI-mediated learning activities, addressing concerns about students encountering inappropriate content or developing unhealthy dependencies on AI.

(e) Extended Learning through Interactive Games

Beyond the conversational feature, the case documents the use of AI to generate interactive games based on the classification system in the Compendium of Materia Medica. These games enable students to distinguish between traditional Chinese medicinal herbs such as goji berries, gardenias, and hawthorns.

The games serve as extended learning tasks, particularly suitable for schools with medicinal herb gardens, training students to skillfully introduce the classification, efficacy, and historical value of medicinal herbs when leading visitors. This application demonstrates how AI can connect classroom learning with authentic, real-world applications. The school's medicinal herb garden and the opportunity for students to serve as docents.

(f) School-Based and Contextualized Learning

The case emphasizes the importance of customization and contextualization. Teachers can allow for simple HTML code modifications to ensure the game content is closely aligned with the medicinal herbs actually cultivated on campus, truly achieving school-based and contextualized learning. This customization ensures that the learning experience is relevant to students' immediate environment, enhancing engagement and meaningfulness.

This approach alleviates the pressure on humanities teachers in curriculum design and textbook writing while ensuring that the resulting materials are closely aligned with local context. The balance between AI-generated efficiency and teacher-directed customization represents a productive model for AI integration that preserves teacher agency while leveraging AI's generative capabilities.

V. Analysis and Discussion

A. Patterns of AI Integration across Cases

The two cases presented in this study reveal several consistent patterns in effective AI integration.

(a) Targeted Deployment -- In both cases, AI was used at specific instructional junctures rather than throughout the entire lesson. This targeted approach reflects a sophisticated understanding of AI's role as a strategic enhancement rather than a comprehensive replacement for existing pedagogical practices. The principle that "given the limited time available ... we do not need to introduce AI into every teaching segment" is applicable across disciplinary contexts.

(b) Pedagogical Value Addition -- In each case, AI was used where it could provide unique pedagogical value that would be difficult to achieve through traditional means. In the science case, AI enabled rapid diagnostic assessment and generation of interactive review games. In the humanities case, AI enabled conversational inquiry with a historical figure. Both applications leverage AI's unique capabilities (speed, scalability, and interactivity) rather than attempting to replicate existing instructional practices.

(c) Teacher Agency and Oversight -- In both cases, teachers retained control over the instructional process. AI-generated materials were reviewed and curated by teachers, AI-generated assessments were used to inform teacher decision-making, and AI-mediated interactions were monitored by teachers. This preservation of teacher agency aligns with research emphasizing that AI should serve as a powerful enabler rather than a replacement

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and that human-AI collaboration in the classroom emphasizes the collaborative relationship between teachers and AI in which human teachers receive real-time support from AI tutors.
(d) Efficiency and Scalability -- Both cases demonstrate the remarkable efficiency of AI integration. In the science case, quizzes could be generated within seconds and games in just two to three minutes. In the humanities case, a personalized chatbot could be generated with only a few simple commands. This efficiency addresses a critical challenge in teaching: the time required to create high-quality instructional materials.

B. Theoretical Implications: Extending TPACK through the Cases

The cases provide concrete illustrations of how the i-TPACK and GenAI-TPACK frameworks can be operationalized in practice. The science case demonstrates the integration of Intelligent-Technological Pedagogical Knowledge (i-TPK)—the knowledge of how to use AI tools for specific pedagogical purposes, such as diagnostic assessment and misconception remediation. The teacher's ability to select appropriate AI tools, craft effective prompts, and interpret AI-generated data reflects the development of i-TPK.

The humanities case illustrates the integration of Intelligent-Technological Content Knowledge (i-TCK)—the knowledge of how AI tools can represent and transform specific content areas. The creation of a Li Shizhen chatbot that draws on uploaded textbook materials demonstrates how AI can be used to make historical content accessible and engaging in ways that traditional instruction cannot achieve.

Both cases highlight the importance of AI Ethics—a distinct domain in both the i-TPACK and GenAI-TPACK frameworks. The monitoring capabilities employed in the humanities case, the curation of AI-generated content in the science case, and the attention to accuracy and appropriateness throughout reflect teachers' ethical reasoning in AI use.

The cases also extend the i-TPACK framework by demonstrating the importance of what might be called curatorial knowledge (the ability to critically evaluate, select, and modify AI-generated content). This dimension of teacher knowledge is not fully captured in existing frameworks but emerges as essential from the cases. As research on AI-generated lesson plans has shown, such content often requires teacher-initiated modifications to successfully support learners with diverse needs. The teachers in these cases demonstrated this curatorial capacity, modifying AI-generated games and curating chatbot responses to ensure pedagogical quality.

C. Disciplinary Differences and AI Applications

The cases also reveal disciplinary differences in how AI can be most effectively applied:
(a) Science Education -- In the science case, AI was used primarily for diagnostic assessment and misconception remediation. These applications address the challenge of teaching abstract, invisible phenomena by providing teachers with data about student understanding and generating engaging practice materials. The focus on misconceptions is particularly appropriate for science education, where conceptual change is a central pedagogical challenge.
(b) Humanities Education -- In the humanities case, AI was used primarily for conversational inquiry and contextualized learning. These applications address the challenge of making historical figures and cultural knowledge accessible and engaging. The use of a chatbot to simulate conversation with a historical figure enables a mode of inquiry that would be difficult to achieve through traditional instruction.

These disciplinary differences suggest that effective AI integration requires attention to the specific pedagogical challenges and opportunities of each subject area. A one-size-fits-all approach to AI integration is unlikely to be effective; rather, teachers need support in identifying how AI can address the specific challenges of their discipline.

D. Critical Tensions in AI Integration

The cases reveal several tensions that merit critical examination.
(a) Efficiency versus quality -- The remarkable efficiency of AI content generation (quizzes in seconds, games in minutes) raises questions about quality. As research has shown, AI-generated lesson plans can be "decidedly boring, traditional, and uninspiring". The cases address this tension through teacher curation and modification, but the risk of prioritizing efficiency over quality remains. The teachers in these cases invested time in reviewing and modifying AI-generated content, suggesting that the efficiency gains may be partially offset by the need for quality assurance.
(b) Personalization versus standardization -- AI enables personalized learning at scale, but there is a risk of standardization—all students receiving similar AI-generated content regardless of their unique needs. The cases address this through data-driven differentiation, but the extent to which AI-generated materials can truly address

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individual learner differences remains an open question. Research has found that AI-generated lesson plans have minimal alignment with UDL/UDT, suggesting that personalization may be more aspirational than actual.
(c) AI assistance versus teacher deskilling -- There is a risk that reliance on AI for tasks such as quiz generation and lesson planning could lead to teacher deskilling—the erosion of professional capabilities that are essential for effective teaching. The cases preserve teacher agency through curation and oversight, but the long-term impact on teacher professional development remains uncertain. As Frosig and Romero (2024) caution, GenAI has "the potential to negatively affect professional agency".
(d) Access versus equity -- AI tools can increase access to personalized learning resources, but they may also exacerbate existing inequities. Not all schools have the technical infrastructure or teacher expertise required for AI integration, raising concerns about the widening digital divide. The cases were implemented in schools with access to a dedicated AI platform, which may not be representative of broader educational contexts.

E. The Role of AI in Addressing Persistent Pedagogical Challenges

Both cases address persistent pedagogical challenges that have long been recognized in educational research.
(a) The Prior Knowledge Problem -- Teachers have always struggled to gauge students' prior knowledge before instruction begins. Traditional approaches (such as informal questioning or pre-tests) are time-consuming and often imprecise. AI-powered diagnostic assessment provides a solution that is both efficient and systematic, enabling teachers to identify knowledge gaps before instruction begins.
(b) The Differentiation Challenge -- Teachers have always struggled to provide differentiated instruction that meets the diverse needs of learners. AI-powered generation of supplementary materials and targeted interventions provides a scalable solution to this challenge, enabling teachers to address individual student needs without the extensive preparation time that would otherwise be required.
(c) The Engagement Problem -- Teachers have always struggled to maintain student engagement, particularly for challenging or abstract content. AI-generated interactive games and conversational agents provide new tools for engaging students in ways that are qualitatively different from traditional instruction.
(d) The Experiential Gap -- Teachers have always recognized the importance of hands-on experience for conceptual development, yet students increasingly lack opportunities for such experience. AI-generated scenarios and interactive materials (Jin et al., 2025) can help bridge this gap, providing virtual experiences that supplement limited hands-on opportunities.

F. Limitations and Cautions

While the cases presented in this study demonstrate the potential of AI-powered teaching transformation, several limitations and cautions must be acknowledged.
(a) Generalizability -- The cases are drawn from specific contexts (second-grade science and fifth-grade humanities) and may not be directly applicable to other grade levels or subject areas. Further research is needed to examine AI integration across a broader range of educational contexts.
(b) Sustainability -- The cases document initial implementation but do not address the sustainability of AI integration over time. Questions about teacher training, ongoing technical support, and the long-term impact on student learning remain unanswered. Research has noted that without well-structured, ethically informed professional development, teachers may struggle to sustain effective AI integration.
(c) Equity Concerns -- The cases do not address equity issues related to AI access and implementation. Not all schools have the technical infrastructure or teacher expertise required for AI integration, raising concerns about the potential for AI to exacerbate educational inequalities. As researchers have noted, this divide, AI risks exacerbating educational disparities rather than mitigating them.
(d) Ethical Considerations -- While the cases address safety through monitoring capabilities, broader ethical considerations such as data privacy, algorithmic bias, and the potential for student dependency on AI are not fully addressed. A systematic review found that "privacy and security" are among the key challenges of generative AI in education. The cases do not provide detailed information about how student data was protected or how algorithmic bias was addressed.
(e) Content Quality -- The cases assume that AI-generated content meets pedagogical quality standards, but research has raised significant questions about the quality of AI-generated educational materials. The cases address this through teacher curation, but the extent to which this curation is sufficient to ensure quality remains uncertain.
(f) Potential Bias -- The cases were implemented using a specific AI platform (GoodClass.ai), and the relationship between the researchers and the platform developer should be acknowledged. While the analysis

focuses on pedagogical practices, the findings may reflect the affordances and limitations of this particular platform.

As noted in the literature, AI provides timely and precise data that significantly deepens the understanding of student learning processes, yet researchers issue a critical caution regarding its implementation in schools. The effective integration of AI in education requires ongoing attention to these ethical and practical considerations.

VI. Implications and Recommendations

A. Implications for Practice

The cases presented in this study have several implications for educational practice.

(a) Strategic, not Comprehensive, Integration -- Schools and teachers should focus on strategic AI integration at specific instructional junctures rather than attempting comprehensive AI adoption across all lessons. This targeted approach is more feasible and more likely to yield meaningful pedagogical benefits. The principle of targeted deployment (using AI where it provides unique value rather than attempting to AI-fy everything) should guide implementation decisions.

(b) Teacher Curation and Agency -- AI-generated content should not be adopted wholesale. Teachers must serve as curators, critically evaluating, selecting, and modifying AI-generated materials to ensure pedagogical quality and appropriateness. This curatorial role is essential for addressing concerns about AI-generated content quality and requires professional development that supports teachers in developing curatorial skills.

(c) Teacher Training and Support -- Effective AI integration requires teacher training that addresses both technical skills and pedagogical understanding. The i-TPACK framework provides a useful structure for such training, emphasizing the integration of AI-Technological, AI-Content, AI-Pedagogical, and AI-Ethical knowledge. Professional development should be pedagogically grounded, ethically responsive, and adaptable across educational contexts.

(d) Infrastructure and Access -- Schools need appropriate technical infrastructure for AI integration, including reliable internet access, compatible devices, and access to AI platforms. However, attention to equity is essential to ensure that AI integration does not exacerbate existing educational disparities.

(e) Curriculum and Assessment Alignment -- AI integration should be aligned with curriculum objectives and assessment practices. The cases demonstrate how AI can support, rather than replace, existing curriculum goals.

B. Implications for Policy

The findings also have implications for educational policy.

(a) Investment in AI Infrastructure -- Policymakers should invest in the technical infrastructure required for AI integration, including broadband access, devices, and AI platforms, while ensuring equitable access across schools and communities.

(b) Professional Development -- Policies should support ongoing professional development for teachers in AI integration, recognizing that effective use of AI requires both technical and pedagogical expertise. The i-TPACK framework provides a research-informed model for such professional development.

(c) Ethical Guidelines -- Clear ethical guidelines for AI in education are needed, addressing data privacy, algorithmic transparency, and appropriate use of AI in instructional contexts. As Wang, Wang, and Su (2024) recommended that "educational organizations should formulate guidelines for the ethical use of AI in education".

(d) Research and Evaluation -- Ongoing research and evaluation are needed to assess the impact of AI integration on student learning and to identify effective practices that can be scaled across educational contexts. Particular attention should be paid to equity implications and the long-term sustainability of AI integration.

C. Future Research Directions

Several directions for future research emerge from this study.

(a) Longitudinal studies -- Research is needed on the long-term impact of AI integration on student learning outcomes, engagement, and motivation. Questions about retention, transfer, and the development of higher-order thinking skills remain unanswered.

(b) Comparative studies -- Research comparing AI-enhanced instruction with traditional instruction across different subjects and grade levels would help identify the conditions under which AI integration is most effective. Such studies should also compare different AI platforms and approaches to identify best practices.

(c) Student perspectives -- Research examining student perspectives on AI-enhanced instruction would provide valuable insights into the learner experience. How do students perceive AI-generated content? What aspects of AI-enhanced instruction do they find most and least valuable?
(d) Teacher professional development -- Research on effective models for teacher professional development in AI integration would support the scaling of effective practices. The i-TPACK framework provides a starting point for such research.
(e) Equity and access -- Research examining equity issues related to AI integration (including differential access, impact, and outcomes) would help ensure that AI benefits all students. Particular attention should be paid to the digital divide and its implications for AI integration. Further research is needed on the quality of AI-generated educational content (Katyayan, Leung & Chan, 2025) and the conditions under which such content meets pedagogical standards. Research (Lammert et al., 2024) has found that "AI-generated lesson plans have minimal alignment with UDL/UDT", suggesting that significant quality concerns remain.
(f) Ethical AI integration -- Research is needed on the ethical dimensions of AI integration, including data privacy, algorithmic bias, and student data protection. The integration of ethics as a distinct domain in the i-TPACK and GenAI-TPACK frameworks provides a foundation for such research.

VII. Conclusion

This case study has examined AI-powered intelligent transformation in teaching through detailed analysis of two instructional cases: a second-grade science lesson on magnets and a fifth-grade humanities lesson on Li Shizhen. The findings demonstrate that AI can be strategically integrated at specific instructional junctures (pre-class diagnostics, misconception remediation, conversational inquiry, and interactive game-based learning) to enhance teaching effectiveness while respecting teachers' limited preparation time.

The cases reveal consistent patterns in effective AI integration: targeted deployment at points of pedagogical value, preservation of teacher agency and oversight, and remarkable efficiency in generating instructional materials. They also reveal disciplinary differences in AI applications, with science education benefiting particularly from AI's diagnostic and misconception remediation capabilities, and humanities education benefiting particularly from AI's conversational and contextualization capabilities.

The study contributes to the growing body of literature on AI-enhanced pedagogy by providing concrete, replicable examples of AI integration across disciplinary contexts. It articulates a framework for thoughtful, balanced AI adoption that preserves teacher agency while leveraging AI's unique capabilities for personalization, scalability, and interactive engagement. The theoretical grounding in TPACK and its extensions (i-TPACK, GenAI-TPACK, and HCAP) provides a foundation for understanding the knowledge and skills teachers need for effective AI integration.

However, the study also highlights significant limitations and cautions. Research on AI-generated content quality has found that such content can be decidedly boring, traditional, and uninspiring and may lack the specificity needed to provide novel ideas for experienced teachers. The cases address this through teacher curation, but the extent to which this curation is sufficient to ensure quality remains uncertain. Concerns about the digital divide, algorithmic bias, data privacy, and teacher deskilling require ongoing attention.

As the integration of AI into education continues to accelerate, thoughtful frameworks that balance the promises and perils of AI are essential. The i-TPACK and GenAI-TPACK frameworks, with their emphasis on ethical integration and human-AI collaboration, provide valuable guidance. As Wang, Wang, and Su (2024) conclude, educators should embrace future trends in AI education instead of shunning its use while guiding students to treat it as a thought aid and reference, rather than relying on it entirely.

The cases presented in this study suggest that AI-powered teaching transformation is achievable—but only with thoughtful implementation that respects the complexity of teaching and learning, preserves teacher agency, and addresses the ethical and practical challenges that accompany any significant educational innovation. The aspiration is that AI-assisted instruction can present a richer and more comprehensive picture of teaching and learning, but realizing this aspiration requires ongoing research, critical reflection, and a commitment to equity and ethical practice.

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