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# Research on AI-empowered teaching in physical geography courses

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**Abstract.** Artificial Intelligence (AI) technology is transforming talent cultivation models and teaching practices in higher education. Physical Geography is a core foundational course in the Geography Science major. Its content system is complex and wide-ranging, spans large spatiotemporal scales, and closely integrates theory with practice; therefore, traditional teaching models face numerous practical challenges. This paper reviews the policy background of AI empowering higher education and the current research status of geography teaching, analyzes the value of integrating AI technology into Physical Geography course teaching, and, by combining literature research and case analysis, examines the current situation of AI-empowered Physical Geography teaching. It summarizes the main problems, analyzes their causes, and proposes teaching strategy recommendations from four aspects: teaching resource development, teaching model innovation, faculty capacity improvement, and evaluation system reconstruction. The study concludes that the key to AI-empowered Physical Geography teaching lies in establishing a "human-AI collaborative" teaching ecology. While fully leveraging technological advantages, it is important to prioritize the cultivation of higher-order abilities such as critical thinking.

**Keywords:** artificial intelligence, physical geography course, geography science, teaching reform, human-AI collaboration

## 1. Introduction

### 1.1. Research background

In recent years, Artificial Intelligence (AI) technology has developed rapidly, exerting an impact on all walks of life. In the field of education, AI has gradually moved from an auxiliary tool into the core of teaching, and the ways of knowledge transmission and the objectives of ability cultivation have changed accordingly.

From the policy perspective, the state has continuously promoted the integration of AI and education in recent years. In 2025, the Ministry of Education launched and implemented the *National Education Digitalization Strategic Action 2.0*, listing intelligence as one of the strategic directions and advancing the application of AI in education. The Ministry of Education and eight other departments jointly issued the *Opinions on Accelerating the Digitalization of Education*, proposing to "coordinate the integrated

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advancement of AI education in primary, secondary, and higher education, build 'general + distinctive' AI general education courses in universities, and develop a number of smart courses in universities"[1]. In the same year, the Ministry of Education issued documents such as the *Guidelines for AI General Education in Primary and Secondary Schools* and the *Guidelines for Teachers' Application of Generative AI* to guide schools at all levels and of all types in organizing AI applications. The *Outline of the Plan for Building a Strong Education Nation (2024–2035)* also emphasizes promoting AI to assist educational reform.

Geography is a highly comprehensive and interdisciplinary discipline, and its integration with AI technology has a disciplinary foundation. Geographical research is spatial, dynamic, and complex, and has a sustained demand for technical means in data acquisition, information processing, model simulation, and other links. Physical Geography is a foundational core course in the Geography Science major, covering elements such as climate, hydrology, geomorphology, soil, and vegetation. Its knowledge system is complex and its spatiotemporal scales span widely. Relying solely on classroom lectures and textbook reading, students find it difficult to form a systematic cognitive framework, which leaves room for the introduction of AI technology.

## 1.2. Research status

In recent years, research on the integration of artificial intelligence and geography education has grown rapidly, mainly focusing on the following aspects. First, theoretical discussions and value interpretations of AI-empowered geography teaching. Researchers generally agree that the combination of AI and geography education is a need arising from the development of geography education itself [1]. The technical characteristics of generative AI have brought about changes in geography education, and its iterative capacity helps deepen students' understanding of geography learning. Some scholars, using the Substitution, Augmentation, Modification, Redefinition (SAMR) model as a framework, have discussed the impact of generative AI on geography education, involving curriculum systems, teaching methods, assessment approaches, and fieldwork. Second, research on the specific application of AI in geography teaching. Multimodal generative AI, through means such as text generation, image generation, 3D modeling, and video generation, has changed the way geography teaching content is organized and has expanded teaching resources [2]. At the higher education level, large language models have been applied in geographic information teaching. Some studies show that LLMs can reduce teachers' lesson preparation pressure, accelerate the updating of teaching resources, and provide students with real-time assistance in software operation and code debugging. In terms of Physical Geography courses, some scholars have designed a blended teaching model supported by geographic data, driven by intelligent algorithms, and carried by virtual-real immersion, relying on intelligent platforms to carry out practices such as pre-class learning diagnosis, in-class collaborative modeling, and post-class knowledge graph generation. Other studies have proposed pathways for AI-empowered teaching reform in Physical Geography courses from four stages: pre-class preparation, classroom interaction, after-class Q&A, and pre-exam review. Third, research on the risks and

[1] Ministry of Education of the People's Republic of China, Cyberspace Administration of China, National Development and Reform Commission of the People's Republic of China, Ministry of Science and Technology of the People's Republic of China, Ministry of Industry and Information Technology of the People's Republic of China, Ministry of Public Security of the People's Republic of China, Ministry of Finance of the People's Republic of China, Ministry of Human Resources and Social Security of the People's Republic of China, National Data Administration. Opinions of Nine Departments Including the Ministry of Education on Accelerating the Digitalization of Education[EB/OL]. (2025-04-11). https://www.gov.cn/zhengce/zhengceku/202504/content_7019045.htm

challenges of geography education in the AI era. While affirming the value of AI empowerment, the academic community has also noted the problems that technology application may bring. Some studies point out that the application of generative AI in geography education prompts people to reconsider the essence of education. How to balance AI-assisted teaching and the cultivation of students' independent thinking ability is a question that needs to be answered in teaching practice. The application of large language models in GIS teaching also shows that AI has a facilitating effect, but it needs to be combined with human-AI collaboration and result review mechanisms.

Looking at existing research as a whole, the academic community has achieved preliminary results in AI-empowered geography education, but there is still room for further advancement. First, most existing studies take secondary school geography education as their object, while research targeting undergraduate students majoring in Geography Science at universities is relatively scarce. Second, research on Physical Geography course teaching reform mostly focuses on diagnosing the problems of traditional teaching models, and discussion of AI-empowered pathways is not sufficiently in-depth. Third, there are still few achievements that examine AI-empowered Physical Geography courses from the full process of "teaching–learning–assessment" [3].

### 1.3. Purpose and significance

This study aims to discuss the theoretical foundations, practical pathways, and safeguard mechanisms of AI technology empowering the teaching of Physical Geography courses for undergraduate students majoring in Geography Science, so as to provide references for the intelligent teaching reform of Physical Geography courses in universities. The theoretical significance of this study lies in enriching theoretical research on the integration of artificial intelligence and higher education, broadening the research scope of geography subject pedagogy, and providing a framework for analyzing the interactive relationship among "technology–teaching–discipline". Its practical significance lies in proposing actionable teaching strategy recommendations through an examination of the current situation and an analysis of existing problems, thereby providing references for curriculum development, teaching reform, and talent cultivation in the Geography Science major, as well as offering insights for the intelligent transformation of Physical Geography courses in similar institutions.

## 2. Research design and implementation

### 2.1. Research approach

This study follows the main line of "theoretical review—current situation investigation—problem diagnosis—strategy construction". First, the literature research method is used to review the policy background, theoretical progress, and practical cases of AI empowering higher education, thereby forming the theoretical foundation of the study. Second, the case analysis method is adopted to select representative cases of AI teaching in university Physical Geography courses for analysis, summarizing experiences and problems. Third, the investigation results are analyzed to diagnose the main problems and their causes in current AI-empowered Physical Geography teaching. Finally, based on the results of problem diagnosis, teaching strategy recommendations are proposed from multiple dimensions.

### 2.2. Data collection and analysis

The data collection of this study mainly adopts the literature research method and the questionnaire survey method. Literature sources include: journal articles and dissertations retrieved from the China National

Knowledge Infrastructure (CNKI) database using keywords such as "artificial intelligence", "Physical Geography teaching", "geography education", and "AI empowerment"; policy documents and meeting minutes published on the official website of the Ministry of Education of China; and relevant reports and teaching and research activity records on teaching reform in Geography Science majors at various universities. Information such as application scenarios, implementation pathways, effect evaluation, and existing problems of AI-empowered Physical Geography teaching is extracted from the literature. The questionnaire survey mainly investigates and statistically analyzes the current situation of AI-empowered university teaching from the perspectives of teachers and students.

In terms of case selection, this study focuses on existing practices, such as the AI-integrated undergraduate course development innovation cases of the College of Urban and Environmental Sciences, Peking University, including courses such as Field Ecology and Comprehensive Physical Geography Field Practice[2], and the AI-empowered Physical Geography curriculum reform practices at Nanjing Xiaozhuang University [4]. By comparing practical cases from different universities, different courses, and different technical routes, the success factors and constraining factors are identified.

# 3. Research results

## 3.1. Survey results of the current situation

### *3.1.1. Main application scenarios of AI in physical geography teaching*

From existing practices, the application of AI in Physical Geography course teaching mainly falls into the following categories. First, intelligent generation of teaching resources. The knowledge system of Physical Geography is complex, involving multiple elements such as climate, hydrology, geomorphology, soil, and vegetation. The static presentation of traditional textbooks cannot fully demonstrate the dynamics and complexity of geographical phenomena. Teachers can use AI to gain an in-depth understanding of geomorphological knowledge and typical cases in their region and quickly generate material resources that match the teaching content. Specifically, AI can produce descriptions of geographical processes and case analyses through text generation technology, transform abstract Physical Geography concepts into intuitive visual materials through image generation technology, and construct three-dimensional models of geomorphological forms and geological structures through 3D modeling technology, thereby expanding the breadth and depth of teaching resources and lowering students' cognitive threshold [5]. Second, classroom interaction and learning diagnosis. Intelligent teaching tools provide new technical support for optimizing the classroom ecology. In classroom teaching, AI can support interactive forms such as real-time Q&A, instant voting, and bullet-screen discussions, and generate learning analysis reports based on students' feedback data, helping teachers accurately grasp students' learning status and comprehension difficulties and dynamically adjust the teaching pace and content focus accordingly. Relying on intelligent teaching platforms such as Xuexitong, teachers can conduct pre-class learning diagnosis to understand students' knowledge base and organize in-class collaborative modeling to promote students' collaborative inquiry, thereby achieving a shift

[2] College of Urban and Environmental Sciences, Peking University. Multiple Teaching Cases from the College of Urban and Environmental Sciences Selected as Peking University Innovation Cases in Practical Teaching and AI-Integrated Undergraduate Course Development[EB/OL]. (2025-10-11). https://ues.pku.edu.cn/xyxw/3068a7ccc6d74e00836c4061eca66053.htm

in teaching decision-making from "experience-driven" to "data-driven". Third, virtual simulation and experimental teaching. Physical Geography teaching involves a large number of geographical processes that are difficult to observe directly, such as plate movement, climate change, and geomorphological evolution.

Limited by spatiotemporal scales and experimental conditions, traditional teaching finds it difficult to present their complete processes. AI can assist in developing virtual simulation experimental platforms for geography, simulating complex geographical phenomena and their evolutionary processes, allowing students to observe natural laws, manipulate experimental variables, and verify theoretical hypotheses in virtual scenarios [6]. The understanding, reasoning, and generation functions of generative AI make the experimental classroom more interactive and comprehensive. Students are no longer passive observers of experimental procedures but active participants who can interact with the virtual environment in real time and explore independently. Fourth, after-class tutoring and personalized learning. The after-class segment is an extension and supplement of classroom teaching and an important stage for students to consolidate knowledge and deepen understanding. AI can play a role in after-class Q&A, pre-exam review, and other stages by providing instant response and personalized support. On the one hand, AI can provide students with round-the-clock Q&A services, quickly responding to problems encountered in homework completion and knowledge review; on the other hand, AI can push targeted exercises and review materials based on students' learning data and weak areas, generate personalized knowledge graphs and learning paths, and thus to a certain extent make up for the lack of personalized guidance under the traditional "one-to-many" classroom model.

*3.1.2. Preliminary feedback from teachers and students*

From existing practices, AI-empowered Physical Geography teaching has been preliminarily recognized by teachers and students. At the teacher level, the introduction of AI tools has effectively reduced lesson preparation pressure. Physical Geography course content updates quickly and is highly interdisciplinary. Teachers often need to invest a great deal of time in collecting materials, organizing cases, and making courseware, while AI can assist in information retrieval, material generation, and framework organization, significantly improving lesson preparation efficiency. At the same time, it accelerates the updating and iteration of teaching resources, enabling classroom content to reflect frontier developments of the discipline in a timely manner. Data in Table 1 show that the most direct feeling of teachers in AI application is the improvement of lesson preparation efficiency and the expansion of teaching resources. More than 80% of teachers recognize the role of AI in saving lesson preparation time and expanding teaching resources, and quantitative research further confirms that lesson preparation time can be reduced by about 30% to 50%. In addition, 65.0% of teachers regard "improving efficiency" as the primary motivation for using AI, and 60.7% list "reducing burden" as an important reason, indicating that the value of AI in reducing teachers' workload has been widely recognized. At the student level, most students hold a positive attitude toward the role of AI in Q&A tutoring and experimental guidance. AI can provide instant response and personalized feedback, helping students break through difficult points in learning, and has played a positive auxiliary role especially in experimental operations and data analysis. Data in Table 2 show that students' acceptance of and satisfaction with AI-assisted learning are generally high. In geography teaching scenarios, 83% of students expressed high satisfaction with VR and AI-driven tutoring tools. The proportion of students with a high level of understanding increased from 33% under traditional teaching to 68% under AI teaching conditions, and the average understanding score increased from 2.2 to 4.7 (on a 5-point scale). In terms of personalized learning, AI-driven personalized learning platforms can increase students' learning satisfaction by 8.9%, and students using personalized learning paths scored about 15% higher in exams than non-users.

**Table 1.** Survey data on the effects of AI application on the teacher side

| Survey Dimension | Specific Indicator | Data |
|---|---|---|
| Time saved in lesson preparation | Proportion of teachers who believe AI can save lesson preparation time | 82.00% |
| Expansion of teaching resources | Proportion of teachers who believe AI can help expand teaching resources | 85.17% |
| Quantified time saved in lesson preparation | Weekly lesson preparation time saved after using AI | 25.3minutes on average |
| Quantified time saved in lesson preparation | Time saved by teachers who use AI regularly every week | 5.9 hours/week on average |
| Efficiency of teaching material preparation | Average reduction ratio in material preparation time | 58.9% |
| Motivation for use | Proportion of teachers using AI to improve efficiency | 65.0% |
| Motivation for use | Proportion of teachers using AI to reduce burden | 60.7% |

**Table 2.** Survey data on students' experience with AI-assisted learning

| Survey Dimension | Specific Indicator | Data |
|---|---|---|
| Satisfaction with Q&A and tutoring | Proportion of students highly satisfied with VR and AI tutoring tools | 83% |
| Effectiveness of Q&A and tutoring | Proportion of teachers who consider AI tutoring tools highly effective | 77% |
| Improvement in comprehension | Proportion of students with a high level of understanding (AI teaching vs. traditional teaching) | 68% vs 33% |
| Average comprehension score | Average score (AI teaching vs. traditional teaching, on a 5-point scale) | 4.7 vs 2.2 |
| Learning engagement | Proportion of students with high engagement with VR and AI tutoring tools | 76% |
| Personalized learning support | Increase in learning satisfaction brought by AI personalized learning platforms | 8.9% |
| Personalized learning support | Increase in exam scores of students using AI personalized learning paths | 约15% |

## 3.2. Main problems

### *3.2.1. Superficial application of technology*

Currently, the application of AI in Physical Geography teaching mostly remains at superficial levels such as basic Q&A and resource generation, and has not truly entered the core of teaching. Physical Geography focuses on the understanding and construction of complex geographical processes, the cultivation of geographical thinking, and the training of cross-scale correlation analysis abilities. These goals require students to undergo a deep cognitive process from phenomenon perception to mechanism understanding, and

from element analysis to systematic synthesis. However, in existing practice, AI is mostly used to quickly retrieve information, generate courseware materials, or answer factual questions, and has not been effectively embedded in the above-mentioned higher-order cognitive links. Some teachers simply equate AI with an "intelligent search engine" or a "courseware generator", viewing it merely as a tool to improve lesson preparation efficiency, while neglecting AI's deeper teaching value in scenario creation, cognitive scaffolding construction, and dynamic assessment. The tendency toward superficial application not only limits the release of AI's potential in empowering teaching, but may also lead students to develop dependent usage habits toward AI tools, which is instead detrimental to the development of independent thinking ability and comprehensive geographical thinking.

*3.2.2. Uneven digital literacy among teachers*

AI-empowered teaching places new demands on teachers' digital literacy, yet the overall AI literacy of current Physical Geography course teachers is still difficult to match this requirement. Some teachers have limited understanding of the basic principles, functional boundaries, and applicable scenarios of AI technology, and lack the ability to systematically integrate AI into instructional design—they may be able to use a certain AI tool to complete simple tasks, but find it difficult to purposefully select, combine, and optimize AI tools according to teaching objectives, content characteristics, and student needs, let alone embed AI into the complete teaching chain of "pre-class—in-class—after-class". In teaching and research activities, "how to balance AI-assisted education and teaching with the cultivation of students' independent thinking ability" has become a focus of widespread concern among teachers. This reflects that some teachers are still unclear about the role positioning of AI: they worry that over-reliance on AI will weaken students' independent thinking ability, while also lacking systematic understanding and practical experience of how to achieve "human-AI collaboration". The superposition of such conceptual hesitation and insufficient ability often makes the application of AI in Physical Geography teaching superficial, making it difficult to truly transform into teaching effectiveness.

*3.2.3. Insufficient adaptability of the curriculum system and teaching model*

Traditional Physical Geography courses have long faced practical difficulties such as a complex and vast teaching content system, limited total class hours, and a rigid teaching model. Physical Geography covers multiple subfields such as climate, hydrology, geomorphology, soil, and vegetation. Knowledge in each field is relatively independent yet interrelated. Teachers often need to complete the instruction of a large amount of content within limited class hours, while students easily fall into a passive learning state of "knowing the what but not the why". Introducing AI is not simply "superimposing" new technology onto existing courses; rather, it requires systematic reconstruction of course objectives, content organization, and teaching processes—course objectives should shift from knowledge memorization to ability cultivation, content organization should shift from linear arrangement to modularization and structuring, and teaching processes should shift from "teacher-lecture-centered" to "human-AI collaborative inquiry-based learning". However, most universities have not yet completed the transformation from "technology superposition" to "curriculum reconstruction". The application of AI still remains at the level of patching traditional teaching models, such as using AI to generate courseware or using intelligent platforms for sign-in, and has not touched the deep transformation of the teaching structure.

*3.2.4. The assessment system has not been reformed in tandem*

AI-empowered teaching calls for synchronous reform of the assessment system. Currently, the assessment of Physical Geography courses still mainly takes the form of a final closed-book examination, focusing on the examination of knowledge memorization and concept understanding, while the assessment of students' higher-order abilities such as geographical thinking ability, data analysis ability, and problem-solving ability is clearly

insufficient. There is a structural misalignment between this assessment orientation and the ability cultivation goals emphasized by AI-empowered teaching: if teaching methods have already shifted toward inquiry-based, collaborative, and personalized learning, while assessment still mainly focuses on standardized knowledge reproduction, then the teaching value of AI cannot be effectively tested, and students' learning behavior cannot receive positive guidance. In addition, AI has unique advantages in process-based assessment and personalized feedback—for example, identifying students' cognitive weak points through analysis of learning behavior data, and helping students adjust learning strategies through instant feedback—but these functions have not yet been fully developed and utilized in the assessment practice of Physical Geography courses, and the "feedback loop" between assessment and teaching still needs to be established.

#### *3.2.5. Insufficient attention to ethical and security risks*

The application of AI in teaching is accompanied by ethical risks such as data privacy, algorithmic bias, and academic integrity. Generative AI may produce "hallucinated" content (i.e., information that appears reasonable but is actually erroneous), which is particularly worthy of vigilance in Physical Geography teaching: explanations of geographical phenomena often involve the combined effects of multiple factors, and erroneous information generated by AI may have a certain appearance of "reasonableness". If students lack the ability to discern, they may easily accept erroneous content as correct knowledge, thereby affecting the accuracy of teaching content [7]. In addition, the collection and use of student learning behavior data involves privacy protection issues. AI algorithms may produce systematic bias against geographical cases from different regions and cultural backgrounds due to deviations in training data, and the boundary of AI-assisted homework completion is also unclear. At present, in Physical Geography course teaching, the identification, assessment, and prevention mechanisms for AI ethical risks are still incomplete, and relevant usage norms and academic integrity education have not been systematically incorporated into curriculum design, which to a certain extent restricts the standardization and sustainability of AI-empowered teaching.

### 3.3. Cause analysis

#### *3.3.1. Constraints of disciplinary characteristics*

Physical Geography is highly comprehensive and interdisciplinary. Its research content involves the interactions among multiple spheres, including the atmosphere, hydrosphere, lithosphere, and biosphere, and its spatiotemporal scales span multiple levels from the microscopic to the macroscopic. This disciplinary characteristic determines that Physical Geography teaching cannot merely satisfy the transmission of knowledge, but must also focus on cultivating students' spatial thinking, systems thinking, and comprehensive thinking abilities. However, although AI technology has significant advantages in processing standardized and structured knowledge, its capability boundaries remain evident when facing the large number of nonlinear, open-ended, and value-laden problems that exist in Physical Geography. For example, regional comprehensive analysis and human-environment relationship judgment often require multi-factor trade-offs in specific contexts. Such problems are difficult to simplify into standardized computational tasks, and AI finds it difficult to complete them independently. In addition, the causes of Physical Geography phenomena often involve multiple interpretations and uncertainty. Analytical conclusions generated by AI may appear reasonable yet lack disciplinary rigor, requiring teachers to make professional judgments and supplementary corrections. The tension between this disciplinary characteristic and the current capabilities of AI technology constitutes a fundamental constraint on the deep integration of AI into Physical Geography teaching.

#### *3.3.2. Lag in institutional safeguards*

At the national level, multiple policies have been issued to promote AI empowering education, but at the specific implementation level in universities, there is still a lack of complete institutional design and resource

safeguards[3]. The construction and maintenance of AI teaching platforms require sustained funding investment; the improvement of teachers' AI literacy requires systematic training mechanisms; and the evaluation of the effectiveness of AI-integrated teaching requires scientific indicator systems—these safeguards are currently insufficient. From the organizational perspective, AI-empowered teaching involves the coordination and cooperation of multiple departments such as academic affairs, human resources, and information technology, but most universities have not yet established a cross-departmental coordinated promotion mechanism, resulting in dispersed resources and ambiguous responsibilities. From the incentive perspective, teachers need to invest additional time and energy in carrying out AI-integrated teaching innovation, but the existing assessment and evaluation system lacks sufficient recognition and reward for such teaching innovation, making it difficult to form sustained intrinsic motivation. The lag in institutional safeguards means that AI-empowered teaching in most universities remains at the stage of individual teacher exploration, making it difficult to form a large-scale and normalized practice pattern.

#### *3.3.3. Limitations of technological maturity*

AI technologies represented by generative large language models are still subject to technical conditions in their application in Physical Geography teaching. Geospatial analysis skill training has a strong dependence on high-performance computing resources, while the computing infrastructure of most universities is still unable to meet the needs of large-scale AI teaching applications [8, 9]. AI's ability to understand and reason about geospatial data is not yet precise enough, and deviations are likely to occur when dealing with content involving spatial relationships, scale transformation, and regional differences. The factual accuracy and disciplinary rigor of its generated content also require manual review, which means that AI currently cannot independently undertake the tasks of generating and judging teaching content. In addition, there is a rhythmic mismatch between the iteration speed of AI technology and the stability of teaching needs. It is difficult for teachers to continuously keep up in a rapidly changing technological environment while maintaining the stability of teaching plans, which also restricts, to a certain extent, the deep application of AI in Physical Geography teaching.

#### *3.3.4. Gradualness of conceptual change*

Moving from traditional teaching to AI-empowered teaching requires not only updating technical means but also transforming educational concepts. Some teachers hold a wait-and-see or skeptical attitude toward AI, worrying that AI will weaken teachers' subject status or cause teaching to lose its "humanized" warmth. This conceptual inertia is not entirely unfounded—teaching is essentially an interactive activity between people, and teachers' emotional investment, value guidance, and personal exemplification are difficult for AI to replace. However, viewing AI as an opposing force and rejecting it is equally unfavorable to the advancement of teaching reform. The gradualness of conceptual change means that the promotion of AI-empowered teaching requires a process; it cannot be rushed, nor can it be passively awaited. Universities should help teachers gradually establish a rational understanding of AI technology through demonstration cases, teaching and research exchanges, and practical experience, and reposition their own teaching roles within the framework of "human-AI collaboration", thereby achieving a conceptual leap from "technology acceptance" to "teaching reconstruction".

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[3] Ministry of Education of the People's Republic of China. Progress and Achievements in Education Digitalization during the 14th Five-Year Plan Period[EB/OL]. (2025-12-30).https://www.moe.gov.cn/fbh/live/2025/77791/twwd/202512/t20251230_1425181.html

# 4. Teaching strategy recommendations

## 4.1. Strategies for teaching resource development

First, build a tiered and categorized AI teaching resource repository. The knowledge system of Physical Geography courses is complex and vast. Corresponding AI teaching resources can be developed according to the levels of "basic concepts—core principles—comprehensive application": the basic level includes knowledge point graphs, conceptual animations, and terminology explanations; the core level includes geographical process simulations, typical case libraries, and data visualization; the comprehensive level includes cross-element correlation analysis, regional comprehensive cognition, and frontier research cases. The resource repository should remain open, making it convenient for teachers to customize and update it according to actual teaching needs. Second, develop virtual simulation and immersive teaching resources. Physical Geography teaching involves many geographical processes that are difficult to observe directly (such as plate movement, climate change, and geomorphological evolution). AI can be combined with technologies such as Virtual Reality (VR) and Augmented Reality (AR) to create immersive and interactive teaching environments. Combining generative AI with VR can provide geography classrooms with more challenging learning scenarios. Third, emphasize the development of localized and regionalized teaching resources. Teachers in different regions can use AI to understand the Physical Geography characteristics of their own regions and generate localized teaching materials. This can not only enhance the relevance of teaching but also help cultivate students' regional cognitive literacy.

## 4.2. Strategies for teaching model innovation

First, build a full-process AI-integrated teaching model covering "pre-class—in-class—after-class". Drawing on existing research, the following arrangement can be formed: before class, use AI for learning diagnosis and personalized preview recommendations; during class, use AI tools to create scenarios, organize interactive inquiry, and provide instant feedback; after class, rely on AI to generate knowledge graphs, push personalized exercises, and provide Q&A tutoring [5]. Second, implement "human-AI collaborative" inquiry-based teaching. In classroom teaching, AI should be positioned as an auxiliary learning tool and cognitive partner, rather than as a source of answers. Teachers can design open-ended geographical questions and guide students to conduct interactive inquiry with AI: students raise questions, AI provides information and analytical frameworks, and students then engage in critical thinking and comprehensive judgment. This can not only leverage AI's information advantages but also help students think independently. Third, promote a shift in the teaching focus from "knowledge transmission" to "ability cultivation". In the AI era, acquiring knowledge is more convenient than ever before. The focus of education should shift from the memorization and reproduction of knowledge to the cultivation of higher-order thinking abilities. Physical Geography teaching should pay more attention to training spatial thinking ability, systems analysis ability, data interpretation ability, and critical thinking ability. AI can serve as a "cognitive scaffold" to help students transition from concrete perception to abstract understanding.

## 4.3. Strategies for improving faculty capacity

First, establish a training system for teachers' AI literacy. Universities should incorporate the improvement of teachers' AI literacy into faculty development plans. Through forms such as special lectures, workshops, and teaching salons, they should help teachers understand the principles of AI technology, master AI teaching tools, and improve their ability to design AI-integrated instruction. Training content should balance technical operations and teaching concepts, avoiding the tendency to "emphasize technology while neglecting

education". Second, encourage teachers to conduct action research on AI-empowered teaching. Teachers can explore pathways for integrating AI with Physical Geography courses in teaching practice and optimize teaching models through the cycle of "practice—reflection—improvement". Universities should provide funding support, platform guarantees, and policy incentives for teachers' teaching and research innovation. Third, build a cross-university collaborative teaching and research community. Relying on platforms such as the MOE Virtual Teaching and Research Section for Geography Science Major, universities should promote experience sharing and collaborative research among Physical Geography course teachers across different institutions. Through the mechanism of "resource sharing—joint problem research—collaborative talent cultivation", the dissemination and updating of AI-empowered teaching experience can be accelerated[4].

### 4.4. Strategies for reconstructing the assessment system

First, build a diversified "process + outcome" assessment system. Necessary summative assessment should be retained, while the proportion of process-based assessment should be increased. AI can record students' learning trajectories, analyze learning behavior data, and generate personalized learning reports, thereby providing data support for process-based assessment. Second, focus on assessing higher-order thinking abilities. Assessment content should expand from knowledge memorization to the examination of geographical thinking ability, data analysis ability, problem-solving ability, and innovation ability. AI can be used to create complex geographical problem scenarios and evaluate students' comprehensive analytical ability in real or simulated situations. Third, establish ethical norms for AI-assisted assessment. When using AI for teaching assessment, the role of AI should be clearly defined: it is an auxiliary tool, not the assessment subject, and the final assessment judgment should still be made by teachers. At the same time, ethical issues such as data privacy protection and algorithmic fairness should be addressed.

## 5. Conclusion and outlook

This study discussed the theoretical foundations, practical status, existing problems, and improvement strategies of AI-empowered teaching in Physical Geography courses for undergraduate students majoring in Geography Science. Driven by national policies, AI-empowered Physical Geography teaching has moved from conceptual advocacy to practical exploration and has achieved preliminary results in teaching resource generation, classroom interaction, virtual simulation, and personalized learning. However, current practice still faces problems such as the superficial application of technology, uneven teacher literacy, insufficient adaptability of the curriculum system, a lagging assessment system, and insufficient attention to ethical risks. The causes involve multiple dimensions, including disciplinary characteristics, institutional safeguards, technological maturity, and conceptual change. On this basis, this study proposed strategy recommendations from four aspects: teaching resource development, teaching model innovation, faculty capacity improvement, and assessment system reconstruction.

Future research and practice can be advanced in the following directions. First, strengthen empirical research by testing the teaching effectiveness of different AI integration models through teaching experiments and effect evaluation. Second, expand technological application by exploring the use of new technologies such

[4] Nanning Normal University. The Third Teaching and Research Activity of the Physical Geography Course Group of the Ministry of Education Virtual Teaching and Research Section for Geography Science Major Successfully Held[EB/OL]. (2025-6-12). https://www.nnnu.edu.cn/info/1114/46399.htm

as multimodal AI and embodied intelligence in Physical Geography teaching. Third, focus on ethical governance by establishing an ethical framework and norms for AI-empowered geography teaching. Fourth, promote interdisciplinary integration by combining the exploration of AI-empowered Physical Geography teaching with teaching reform in disciplines such as Geographic Information Science and Data Science.

## Fundings

The Guangdong Provincial Higher Education Teaching Reform Project-"Reform and Practice of AI-Empowered Physical Geography Teaching Model" (PX-38251098), and 2024 University-Level Education and Teaching Reform Project of Lingnan Normal University-"Research on the Reform and Practice of Physical Geography Teaching Model Based on AI Technology" (PX-92463)

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