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A Review of Generative Artificial Intelligence Applications in Senior High School Geography Teaching

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Abstract. This paper reviews domestic research (2023–2025) on generative AI (GenAI) applications in senior high school geography teaching, analyzing four dimensions: thinking-oriented instruction, test item development, question chain teaching, and implementation strategies. Findings show GenAI is reshaping education in three key ways: (1) transforming classroom structure from teacher-student dual to teacher-machine-student ternary, with teachers shifting from knowledge authorities to learning designers and thinking guides; (2) using high-quality question chains within authentic contexts to support deep learning and higher-order thinking; (3) significantly improving proposition efficiency and test quality, though content accuracy and thinking cultivation remain limited. Current research suffers from insufficient empirical evidence, narrow evaluation dimensions, weak integration of disciplinary characteristics, and limited support for teacher professional development. Future research should prioritize empirical validation, discipline-specific AI tool development, multi-dimensional evaluation systems, teacher AI literacy training, educational equity, and ethical governance. These efforts will promote deep GenAI–geography integration, supporting digital transformation and high-quality education development.

Keywords: Generative Artificial Intelligence, Senior High School Geography, Thinking-Oriented Classroom, Question Chain Teaching, Test Item Development

1. Introduction

The Senior High School Geography Curriculum Standards (2017 Edition, Revised 2020) explicitly proposes "attempting to more extensively utilize big data, artificial intelligence, Internet Plus, and other information technologies to promote the expansion and deepening of geography learning." In 2023, the Ministry of Education issued the Deepening Action Plan for Basic Education Curriculum and Teaching Reform, further emphasizing the need to "deeply advance educational digitalization and promote the deep integration of information technology with education and teaching." Against this backdrop, Generative Artificial Intelligence (GenAI), with its powerful capabilities in content generation, context creation, and personalized interaction, provides new technical support for innovation in senior high school geography teaching [1, 2].

Generative Artificial Intelligence refers to cutting-edge technologies based on complex algorithms, models, and rules that generate content through training on massive datasets and can autonomously produce diverse digital content, including text, images, audio, video, and code.

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Compared with traditional educational technologies, GenAI demonstrates significant characteristics, such as strong autonomous learning adaptability, fast and diverse outputs, and powerful cross-disciplinary integration capabilities, showing tremendous potential for reconstructing teaching models, enriching teaching resources, and promoting personalized learning [2, 3]. Constructivist learning theory emphasizes learners' active construction and the importance of social interaction. Combined with GenAI, it can create more authentic, rich, and interactive learning contexts for students, supporting their deep learning and knowledge construction [4, 5].

2. Application dimensions of generative AI in senior high school geography teaching

2.1. Application in thinking-oriented classroom teaching

Scholars have systematically explored the application of GenAI in senior high school geography-thinking-oriented classrooms. The study proposes that geography-thinking-oriented classroom teaching based on artificial intelligence should meet three core requirements: using AI as teaching support, employing progressive questioning and interactive thinking in the teaching process, and prioritizing students' geography-thinking development in the teaching evaluation.

In terms of teaching process design, the study constructs a four-stage model: creating problem contexts, analyzing and solving problems, applying and transferring knowledge, and monitoring thinking processes. Within this framework, GenAI plays multiple roles: context creator (generating geography problem contexts), intelligent learning companion (providing background materials and thinking guidance), virtual mentor (personalized tutoring and Q&A), and data manager (recording thinking processes and forming cognitive databases). Using "Expanding Blue Economic Space: Safeguarding Maritime Rights and Interests" as a case study, the research demonstrates how tools such as Wenxin Yiyan can be used to generate contextual materials, design five-stage question chains, and support students' thinking advancement. The study also notes that while AI cultivates students' geographical thinking, it has limitations in developing students' map-reading abilities, places higher demands on teachers, and requires vigilance against student thinking inertia.

Teaching theory research indicates that thinking development is the core objective of deep learning, and thinking-oriented classrooms can effectively advance students' thinking progression through problem-driven and scenario design approaches [5-7]. In this process, GenAI can provide intelligent personalized learning support, enabling teachers to transform from knowledge transmitters to value leaders, emotional communicators, and growth motivators.

2.2. Innovative application in test item development

Taking the development of a senior three geography "Atmosphere" unit test as an example, scholars have proposed a complete path for GenAI-assisted proposition. The study divides the proposition process into four stages: proposition preparation, test item design, evaluation and revision, and test item assessment, thereby constructing a cyclic optimization mechanism that involves inputting prompts, questioning GenAI, judging generated content, adjusting prompts, and selective adoption.

Through specific cases, the research demonstrates how tools such as Kimi can be utilized to: (1) generate proposition plans and two-way specification tables; (2) generate multiple-choice questions, comprehensive questions, and scoring standards based on prompts; (3) create authentic contexts incorporating current events (such as California wildfires in the United States); and (4) conduct test quality analysis (difficulty, discrimination, reliability) based on student score data. Research on primary and secondary school teachers' proposition capabilities indicates that current teacher

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proposition work lacks sufficient theoretical support for measurement and evaluation, and the introduction of AI-assisted tools can significantly enhance the scientific rigor and standardization of proposition [8]. The study finds that GenAI can substantially improve proposition efficiency, transforming teachers from test item producers to creative stimulators and proposition decision-makers, while also facing challenges such as lower thinking levels in test items generated by simple prompts, the need for manual figure supplementation, and the need for further optimization of stem materials.

2.3. Application research in question chain teaching

Research on GenAI applications in senior high school geography question chain teaching employs diverse methods, including questionnaire surveys, case studies, and comparative experiments, forming a complete research chain from theoretical construction, status investigation, system building, to empirical validation.

2.3.1. Theoretical framework construction

This study defines the concept of chat-style question chains, which combine AI dialogue mechanisms with problem-based teaching concepts, utilizing AI chatbots' interactive capabilities to construct interrelated question chains. Based on constructivist learning theory, educational informatization theory, and problem-based teaching theory, the study constructs a GenAI-supported question chain teaching framework comprising four core stages: creating geography problem contexts, designing geography question chains, exploring geography question chains, and summary evaluation. The deep integration of inquiry-based learning and question chain teaching can effectively promote students' deep learning and cultivate core competencies in geography [9-11].

2.3.2. Status investigation findings

Through questionnaire surveys of 296 students and 57 teachers, the study reveals: At the student level, 62.16% of students have only heard of but do not understand GenAI, yet 84.12% hold positive attitudes toward AI integration in geography classrooms; 78.38% of students believe AI can automatically generate logically coherent, progressively advancing question chains. At the teacher level: 77.19% of teachers consider question chain teaching very necessary; 70.18% believe GenAI integration in geography teaching is very necessary, but 71.93% indicate that the lack of systematic training and an informatized teaching research atmosphere is the primary obstacle.

2.3.3. Empirical research conclusions

Conducting a comparative experiment with "The Integrity of Natural Environment" as the theme, results show that the experimental class (GenAI-supported question chain teaching) significantly outperformed the control class in both performance-based assessment (geographical practice ability, regional cognition, comprehensive thinking, human-land coordination perspective) and written tests (mean score 26.08 vs. 23.36), validating the effectiveness of this model in promoting students' knowledge system construction and comprehensive ability development.

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2.4. Exploration of application paths and strategies

Scholars have explored practical strategies for GenAI in senior high school geography teaching from two perspectives: value analysis of applications and full-process application paths. The value of GenAI in senior high school geography teaching is mainly manifested in: reconstructing teaching models (transforming from a teacher-student dual structure to a teacher-machine-student ternary structure), enriching teaching resources (dynamically generating personalized learning resources and exercises), and improving teaching evaluation (real-time recording of thinking processes, constructing cognitive databases). Research on educational informatization theory and AI-empowered learning indicates that the deep integration of technology and education requires systematic innovation of teaching models and reconstruction of evaluation systems [2, 12].

3. Research consensus and main viewpoints

3.1. Structural transformation of teaching models

Generative AI has driven a shift in geography teaching from teacher-centered to student-centered, from knowledge transmission to competency cultivation. The teacher-machine-student ternary structure proposed by Hou Yu and colleagues, and the teacher guidance-AI support-student subject framework constructed by Lu Yu, both reflect new human-machine collaborative teaching relationships. This transformation aligns with the development direction of senior high school geography teaching quality improvement under the new curriculum standards and corresponds to the cultivation objectives of core competencies [6]. Teachers' roles have transformed from knowledge authorities to learning designers, thinking guides, and process evaluators.

3.2. Core position of question chains and thinking chains

Multiple studies emphasize that the effective application of GenAI cannot be separated from high-quality question design. Whether Hou Yu et al.'s five-stage geography question chain, Lu Yu's chat-style question chain, or Gao Zhouqian and Zhou Tong's AI chat-style question chain, all advocate utilizing AI's contextual learning capabilities to construct logically progressive, deeply layered question sequences to drive students' higher-order thinking development [5, 9-11]. This aligns with constructivist theory's principle that learners actively construct knowledge.

3.3. Advantages in context creation and personalized learning

GenAI possesses unique advantages in creating authentic contexts and supporting personalized learning. Peng Zilai's utilization of AI to generate California wildfire contexts for test item development, Lu Yu's design of "Time-Traveling Geography Explorer" contextual teaching, and Chen Lin's construction of multi-context learning tasks for Japanese geography all demonstrate AI's potential in breaking through textbook limitations and connecting with the real world [4, 5]. Such applications help students better understand the practical significance of geography as a discipline.

3.4. Boundaries and risks of technology application

Researchers universally recognize the limitations of GenAI: (1) generated content may contain knowledge errors ("knowledge hallucinations"), requiring professional teacher oversight; (2) limited effectiveness in cultivating students' map-reading abilities and spatial thinking; (3) over-reliance

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may lead to student thinking inertia and weakened independent thinking abilities; (4) higher demands on teachers' digital literacy and prompt design capabilities [1, 12, 13]. Ethical risks and educational equity issues are also increasingly prominent.

4. Research deficiencies and future prospects

4.1. Limitations of existing research

4.1.1. Severe insufficiency of empirical research: imbalance between basic theory and empirical validation

Most studies focus on theoretical construction and case design, lacking large-sample, long-term empirical validation. This results in a relatively weak quantitative assessment of GenAI teaching effects and comparative studies on the effectiveness of different application models. Specific manifestations include: (1) lack of quasi-experimental research across regions and grade levels, making it difficult to validate the universality and stability of models; (2) scarcity of long-term tracking studies, unable to assess the impact of technology application on students' sustainable development; (3) insufficient rigor in experimental design and unscientific control variable settings. Establishing standardized teaching measurement and evaluation systems is an important current task [14, 15, 8].

4.1.2. Single evaluation dimension: transition from academic achievement to multi-dimensionality

Existing research predominantly focuses on academic achievement and core competencies, with less attention to the tracking and evaluation of learning motivation, emotional attitudes, and long-term learning effects. This achievement-only evaluation orientation contradicts the comprehensive development philosophy advocated by the new curriculum standards. For instance, there is a lack of dynamic assessment of changes in students' learning motivation and interest development, limitations in evaluation methods for students' innovative thinking and critical thinking, insufficient quantitative evaluation of process indicators such as teacher-student interaction quality and classroom participation, and inadequate consideration of individual learning differences and educational equity. Establishing a multi-dimensional evaluation framework encompassing process-competency-emotion is urgently needed [7, 16, 14].

4.1.3. Inadequate exploration of disciplinary characteristics: missing mechanisms for integrating geography's disciplinary nature with AI

The spatiality, regionality, comprehensiveness, and practicality characteristics of geography require a deeper exploration of integration mechanisms with GenAI. Current research primarily focuses on general teaching design methods, with insufficient investigation of geography-specific teaching principles and the internal mechanisms of technology integration. GenAI lacks deep research on teaching applications that integrate spatial data and Geographic Information Systems (GIS), and there is limited research on the relationship between complex scenario cognition in regional and human geography and AI empowerment. Meanwhile, pathways for integrating practical teaching (field investigations, geography experiments) with AI remain underdeveloped, and AI support mechanisms for comparative geography analysis and comprehensive judgment capabilities remain unclear [17].

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4.1.4. Weak teacher development research: transition from skill training to professional development

Research on improving geography teachers' AI literacy, cultivating prompt design capabilities, and developing human-machine collaborative teaching capabilities is relatively scarce. This is a key bottleneck that constrains the effectiveness of GenAI applications in teaching. Currently, teacher digital literacy evaluation systems remain imperfect, lacking professional standards and diagnostic tools specifically for geography teachers. Systematic AI literacy training courses and institutionalized teacher development support are insufficient, making it difficult to promote teachers' transformation from passive users to active innovators. Meanwhile, cultivation pathways for professional skills such as prompt engineering and human-machine collaborative instructional design remain unclear, and insufficient research attention is paid to the ethical dilemmas and power restructuring issues teachers encounter in practice. Teacher cultivation in the context of current educational digitalization is facing transformation [18-20].

4.2. Future research directions

4.2.1. Deepening empirical research: transition from case exploration to systematic validation

Conduct quasi-experimental research across multiple regions and grade levels with large samples, establishing rigorous control group settings, focusing on validating the effectiveness of different AI application models in promoting students' deep learning and cultivating core competencies. Recommendations include: (1) designing longitudinal tracking studies to examine the long-term effects of AI application on students' academic achievement, thinking development, and learning motivation; (2) conducting cross-regional comparative studies to examine differences in AI application effects across regions with different socioeconomic backgrounds and teacher competency levels; (3) applying new methods such as cognitive neuroscience and learning analytics to deeply explore students' cognitive mechanisms and learning laws under AI empowerment [2, 6, 7].

4.2.2. Developing discipline-specific tools: transition from general AI to specialization

Explore professionalized GenAI teaching tools based on geography, disciplinary knowledge graphs, and spatial datasets. By integrating senior high school geography curriculum standards, college entrance examination evaluation systems, and geography knowledge ontology, construct geography disciplinary knowledge graphs and question banks; based on GIS data, remote sensing imagery, and geographical information professional data sources, develop AI tools integrating spatial thinking; simultaneously design AI-assisted functions targeting geography disciplinary key competencies (map-reading ability, regional cognition, human-land coordination perspective) and establish multi-language, multi-perspective case libraries for regional geography to enrich reserves for context creation [13, 3, 17].

4.2.3. Constructing evaluation systems: transition from single indicators to multi-dimensional frameworks

Establish multi-dimensional evaluation frameworks encompassing process-competency-emotion, focusing on the long-term effects of AI-assisted teaching. In developing process-based evaluation tools, real-time monitoring of student performance during problem-solving and thinking interaction

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processes; in designing competency evaluation scales, systematically assessing the achievement of geography core competencies (regional cognition, comprehensive thinking, human-land coordination perspective); simultaneously constructing emotional attitude evaluation indicators to track changes in students' learning motivation, interest, and self-confidence; exploring big data-based learning analytics methods to provide foundations for personalized evaluation and dynamic adjustment [7, 14-16].

4.2.4. Strengthening teacher training: transition from general training to professional empowerment

Design systematic geography teacher AI literacy training courses to enhance practical capabilities in prompt engineering and human-machine collaborative instructional design. By establishing professional standard systems for primary and secondary school teachers' digital literacy, develop hierarchical assessment frameworks for geography teachers' AI application capabilities [18-20]; develop modular, progressive teacher training courses covering AI fundamentals, prompt design, teaching case analysis, and ethical reflection; construct school-based development platforms supporting peer learning and teaching innovation communities for geography teachers; establish teacher reflection mechanisms encouraging teachers to record practical experiences, resolve teaching dilemmas, and iteratively improve instructional design. Teacher professional development is the key to successful technology integration.

5. Conclusion

Generative Artificial Intelligence brings unprecedented opportunities and challenges to senior high school geography teaching. From thinking-oriented classrooms to test item development, from question chain teaching to full-process applications, researchers have preliminarily constructed theoretical frameworks and practical pathways. However, the educational value of technology ultimately depends on teachers' professional wisdom and the depth of human-machine collaboration. Future research should continue to deepen empirical validation, explore disciplinary characteristics, and support teacher professional development, establishing more standardized and persuasive research systems. Meanwhile, innovative exploration in industry-university-research collaboration should better connect laboratory achievements with school practices, promoting GenAI's transformation from a "teaching auxiliary tool" to an "educational change driver." Only through these efforts can we truly achieve the strategic goal proposed in China's Education Modernization 2035 of accelerating talent cultivation model reform through modern technology, while ensuring this transformation benefits all students, especially those in regions with relatively weak educational resources, ultimately promoting balanced development and high-quality improvement in senior high school geography teaching.

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