

Research Article

AI-Empowered Climate Change Education in High School Geography: A Dual-Graph Approach to Cognitive-Behavioral Transformation

Meiyu Li, Shengqian Zhang^{*}, Jiaxin Lu

School of Geographical Sciences and Planning, Nanning Normal University, Nanning, China

Abstract

This study addresses the persistent challenges of "superficial understanding without depth" and "awareness without action" in current high school geography climate change education. To overcome these limitations, this paper develops an AI-enabled teaching framework that integrates knowledge graphs and competency graphs—collectively termed "dual graphs"—to establish a dual mechanism model for driving "cognition–behavior" transformation. At the cognitive level, the knowledge graph presents climate science concepts in a structured format, while generative AI tools and virtual simulation technologies assist students in conducting systematic knowledge construction and immersive learning experiences. This innovative approach transforms abstract climate concepts into tangible understanding, thereby addressing the issue of fragmented and superficial knowledge acquisition. At the behavioral level, competency graphs define clear developmental pathways and actionable indicators, with AI systems providing personalized feedback, quantitative behavioral tracking, and sustained motivation. This structured support facilitates the crucial transition from climate awareness to concrete, sustainable actions, effectively bridging the "awareness-action gap." The paper further elaborates specific teaching application cases, demonstrating how this framework can be implemented in authentic classroom settings. While analyzing its feasibility, the study also addresses practical challenges including hardware requirements, teacher readiness, and evaluation mechanisms. By offering both theoretical foundations and practical implementation pathways, this research contributes to establishing an operable, evaluable, and effective new model for climate change education within high school geography curricula.

Keywords

Artificial Intelligence (AI), High School Geography, Climate Change Education, Knowledge Graph, Competency Graph, Cognitive-Behavioral Transformation

1. Introduction

Climate change has become a global focus of attention. Frequent extreme weather events, rising sea levels, and other issues are increasingly prominent, drawing significant attention from the international community. International frame-

works and multilateral meetings such as the United Nations Climate Change Conference (COP) and the Paris Agreement continually emphasize the urgency of addressing climate change, reflecting the determination of nations to take col-

^{*}Corresponding author: 499245928@qq.com (Shengqian Zhang)

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lective action [1]. This challenge concerns the survival and development of all humanity, and mitigating its impacts has become an international consensus.

High school students are crucial actors in future society and bear significant responsibility in addressing climate change [2, 3]. Guiding them to understand climate issues, stimulating their awareness of participation, and translating this into practical actions are vital missions of education. High school geography, integrating natural and social knowledge and covering topics such as the atmosphere, the environment, and human-environment relationships, serves as an important vehicle for climate change education. Therefore, it is necessary to strengthen the systematic teaching of climate change-related knowledge in high school geography instruction and focus on guiding students to translate acquired knowledge into concrete actions to mitigate climate change.

However, current climate change education in high school geography still faces challenges: teaching content heavily relies on instructor-led delivery and rote memorization, while knowledge is fragmented or missing in textbooks, lacking effective integration tools. This makes it difficult for students to develop a systematic understanding. As a result, students' knowledge remains "superficial without depth," and even when certain knowledge is acquired, it often fails to translate into action—"awareness without action."

Advances in artificial intelligence (AI) technology provide more convenient teaching conditions and rich resource support for high school geography education. AI technology can compensate for the limitations of traditional teaching in perception, understanding, and behavioral transformation. The integration of knowledge graphs and competency graphs can help students systematically construct knowledge, effectively integrate fragmented climate change concepts, and provide clear guidance for practical transformation by defining behavioral development stages and goals.

This paper takes high school geography as a starting point to explore innovative pathways for AI-enabled climate change education. By constructing a "dual-graph" model that integrates knowledge graphs and competency graphs, it aims to address the issues of shallow cognition and insufficient behavioral transformation in traditional teaching.

2. Current Research Status

Up to now, climate change education is still a relatively weak area in research related to high school geography teaching. In the three core journals of *《Middle School Geography Teaching Reference》*, *《Geography Teaching》* and *《Geography Education》*, the number of studies on the theme of "climate change education" is significantly less compared to hot topics such as "core geographic literacy" and "interdisciplinary teaching" [4, 5]. Research in this field began in the early 2000s and reached a small peak between 2010-2014, with only sporadic results published in the following decade.

In the existing research results, the research content mainly focuses on the knowledge introduction, teaching practice, and application of climate change, and there is relatively little research on theoretical construction. Moreover, teaching practice generally adopts project-based teaching and other models, and no systematic research combining artificial intelligence technology has been found yet [6].

At the technical support level, knowledge graphs and competency graphs, as structured teaching tools, demonstrate significant application potential [7, 8]. At present, research on knowledge graphs in China mainly focuses on the application of technology construction and other fields. There are also studies on the application of knowledge graphs in the field of geography, but research on their integration with high school geography teaching is extremely limited; the research on capability mapping is even rarer, and the integration and application of "dual mapping" in high school geography and climate change education is still an urgent research direction that needs to be explored [9].

In recent years, with the rapid development of artificial intelligence technology, research related to it has gradually increased and become one of the current research hotspots in various fields. In the field of education, the integration of AI technology into teaching has also become a hot topic in recent times. However, the integration of AI and teaching is still an emerging topic, and research on it is still in its infancy. Existing achievements are mostly integrated with the Chinese language subject, and exploration of its application in geography is still limited [10, 11]. Moreover, most of the current research on the integration of AI technology and geography teaching focuses on AI technology providing resource support for teachers, enhancing knowledge presentation effectiveness, assisting students in practice and feedback, etc. The research on combining AI technology with dual graph theory to serve high school geography climate change education has not yet been systematically carried out.

Therefore, this article uses "dual graph" as technical support to attempt to combine "climate change education" with AI technology, focusing on exploring the mechanism and implementation path of AI in promoting students' transformation from climate cognition to practical action, in order to promote the deepening and expansion of research in this direction.

3. Theoretical Framework: A Fusion Model of "Cognition Behavior" Dual Mechanism and "Dual Mapping"

The "cognition behavior" dual mechanism framework constructed in this study, with the knowledge map and ability map as the core technical support, systematically explains how artificial intelligence technology can synergistically promote high school students' knowledge deepening and behavior transformation in climate change learning through

two interrelated and functional actionpaths. The framework is based on constructivist learning theory, Situational Cognition Theory and behavior change theory, forming a complete set of "understanding experience resonance action" function model.

3.1. Cognitive Mechanism: Knowledge Mapping Driving Systematic Knowledge Construction

Cognitive mechanism is the basis for students' behavior transformation. The purpose is to solve the problem that students' knowledge of climate change is "not deep", and help students build a systematic knowledge system by integrating scattered climate change knowledge through the knowledge mapping system. This mechanism can be realized in the following two ways:

The first is to promote the independent construction of students' knowledge with the help of generative artificial intelligence [12]. Based on the knowledge map, teachers can visualize the relationship between climate change related concepts and knowledge, such as greenhouse effect, carbon cycle, extreme weather, etc., and upload them to the AI system to enable them to carry out structured reasoning and response. This is equivalent to providing students with a tireless, all day online "expert" or "thinking partner", and the answers generated by AI are logical and systematic rather than fragmented information due to the support of knowledge map. Students can ask questions at any time through natural language, while AI can decompose complex concepts or knowledge into easy to understand knowledge chains through continuous guidance and decomposition interpretation. Compared with traditional teaching methods, this process emphasizes student-centered, students' initiative to initiate topics, and AI as an assistant to help them actively construct knowledge systems, so as to internalize knowledge into students' own cognition, which perfectly conforms to the core proposition of "learning is learners' active construction of meaning" in Constructivist Learning Theory. This method can effectively solve the pain points of students' "not daring to ask", "not having time to ask" and "not getting personalized answers" in the traditional classroom, and realize the in-depth understanding of knowledge and the construction of personalized meaning.

Secondly, the application of virtual simulation technology can further transform the static knowledge in the knowledge map into an experiential dynamic situation. For example, students can experience climate change in a virtual environment by simulating the dynamic process of glacier melting and sea level rising inundating cities. Situational Cognition Theory believes that learning is deeply rooted in the situation. This immersive experience can enable students to change from the "bystander" of knowledge to the "presence", and make the macro, abstract and slowly evolving process of climate change perceptible and interactive. This can not only deepen students' cognition of knowledge themselves, but also stimulate students' strong sense of presence and shock at

the emotional level, causing emotional resonance, so as to lay the foundation for cultivating students' sense of climate responsibility and promoting their behavior transformation.

3.2. Behavior Mechanism: Stimulating Emotional Motivation and Enabling Behavior Transformation

Behavior mechanism is the key to promote the transformation of students' behavior, which aims to solve the problem of "knowing but not doing". Relying on the ability map, the abstract goals such as "low-carbon life" are taken as operable specific behavior indicators to provide students with a clear route to advance their behavior, and the knowledge and emotional resonance formed by students in the cognitive stage are transformed into real action will and persistent practice [13, 14]. The mechanism is mainly implemented through the following two paths:

First of all, using the data interaction function of AI technology, combined with the behavior stages and goals clearly defined in the ability map, the responsibility association is established. AI can quickly process and analyze data, and guide students to participate in the exploration of climate data closely related to themselves. For example, AI can be used to record and analyze the daily carbon emissions of individuals or families, or visual tools can be used to compare and analyze the temperature, precipitation and other changes in hometown in the past 10-20 years. Through hands-on operation and observation of real data, students can shorten the distance between "global climate change" and "individual life", and more intuitively perceive their own responsibilities. Social cognitive theory emphasizes that "self-efficacy" plays a key role in behavioral motivation: when students see the relationship between their behavior and climate change with the help of AI, and are convinced that they can affect the environment through specific actions, their self-efficacy will be significantly enhanced, so they are more willing to take and adhere to actions.

Secondly, relying on the behavior development path planned by the ability map, AI can provide personalized intelligent feedback and continuous motivation [15]. The ability map decomposes the abstract environmental protection goals into operable and evaluable specific behavior indicators. AI can provide students with real-time, intelligent and personalized feedback and incentives according to these indicators. According to the behavior change theory in psychology, continuous behavior needs motivation and ability, and also needs to be continuously encouraged and strengthened. Students can implement behavior more continuously after receiving the feedback and incentives provided by AI. For example, when students record an environmental behavior, AI can timely calculate the impact of the behavior on climate change and give positive incentives. This intelligent incentive closely linked to the goal of the ability map stage constitutes a powerful cycle of behavior reinforcement, which effectively reduces the psychological cost of students' behavior adherence, continuously stimulates students' intrinsic motivation, and

gradually transforms them from occasional attempts to stable habits.

3.3. Collaborative Fusion and AI Empowerment of "Dual Maps"

In fact, the "cognition behavior" dual mechanism is not an isolated and disjoint path, but an organic whole with cohesion and mutual reinforcement. Through the fusion design of "dual maps", it can achieve organic cohesion and two-way enhancement. Knowledge mapping provides scientific basis and systematic cognitive basis for behavior transformation; Ability mapping provides clear behavior ladder and sustainable

action path for cognitive implementation. As a technology enabling medium, AI dynamically connects the dual maps through the functions of generative dialogue, virtual simulation, data tracking and intelligent feedback, and realizes mutual call and support in the teaching process, forming a benign cycle of "cognitive activation - behavior attempt - feedback adjustment - cognitive deepening". This integration model not only promotes students to establish a systematic and structured knowledge system at the cognitive level, but also provides students with a clear stage of behavior development and goal orientation, and realizes the collaborative promotion of cognitive construction and behavior transformation.

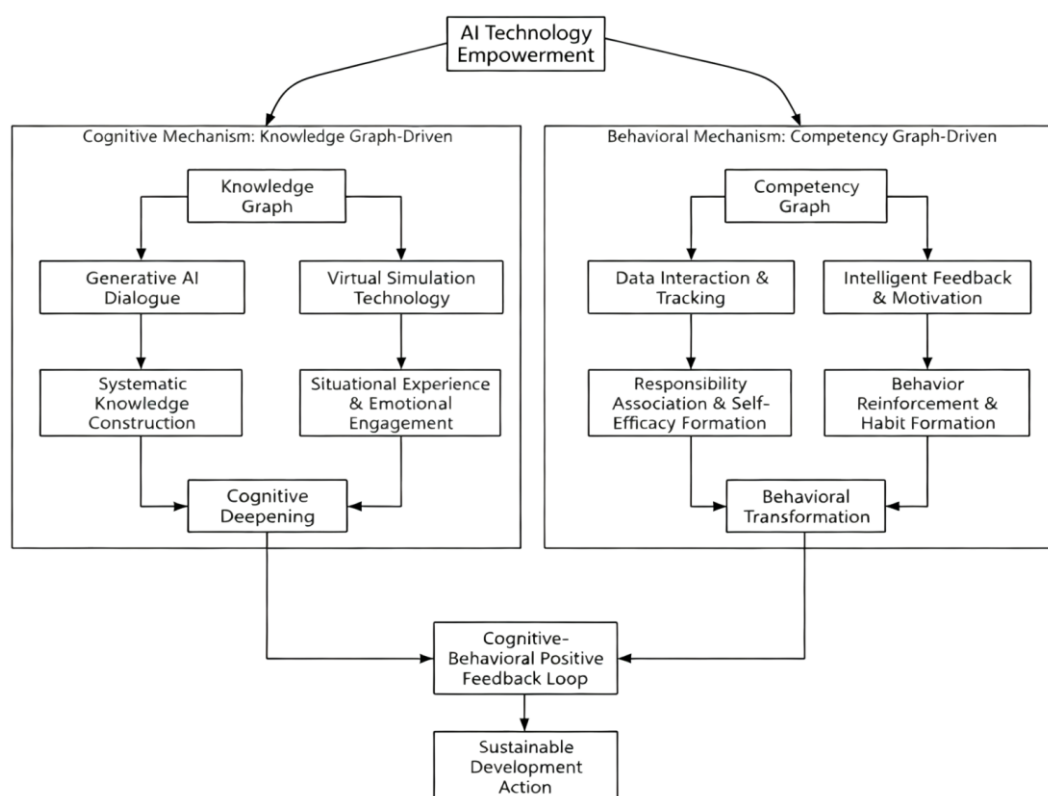


Figure 1. Schematic Diagram of the Dual-Mechanism Integration Model of "Cognition-Behavior" in AI-Empowered High School Geography Climate Change Education.

4. Practical Pathways: Application Design of AI Tools in Teaching

4.1. Application Design Based on Cognitive Deepening

At the cognitive level, the application of AI technology aims to leverage knowledge graphs to transform abstract knowledge into systematic, interactive, and experiential content, thereby promoting the internalization and construction of

student knowledge.

Taking the lesson "Composition and Vertical Layers of the Atmosphere" from the Hunan Education Edition high school geography textbook as an example, the existing textbook only briefly mentions that greenhouse gas emissions cause global warming, lacking systematic explanation and visual support, which makes it difficult for students to form a deep understanding. To address this deficiency, teachers can design teaching activities that integrate generative AI dialogues and virtual simulations based on knowledge graphs. The knowledge graph first systematically integrates relevant concepts and their causal relationships, forming a visual knowledge network structure (as shown in [Figure 2](#)).

During the teaching implementation process, teachers can design a "Dialogue with an AI Climatologist" session, where students, in small groups, use generative AI tools (such as ChatGPT, Deepseek, Douban, etc.) to engage in multi-round questioning and discussion on topics such as "how greenhouse gases lead to global warming" and "the impact of global warming on human society." This encourages students to actively construct the knowledge relationship between the greenhouse effect and climate change. Subsequently, teachers guide students to use AI-driven simulation programs (such as the PhET Interactive Simulation Platform) to conduct virtual

operational experiments. By adjusting greenhouse gas concentration parameters, students can observe real-time global temperature change trends, thereby intuitively understanding the causal mechanism between gas proportions and warming effects.

This process transforms static knowledge in the knowledge graph into a dynamic and interactive learning experience, enabling students to visually comprehend the causal mechanism between the greenhouse effect and climate change, effectively addressing the issue of "superficial understanding without depth."

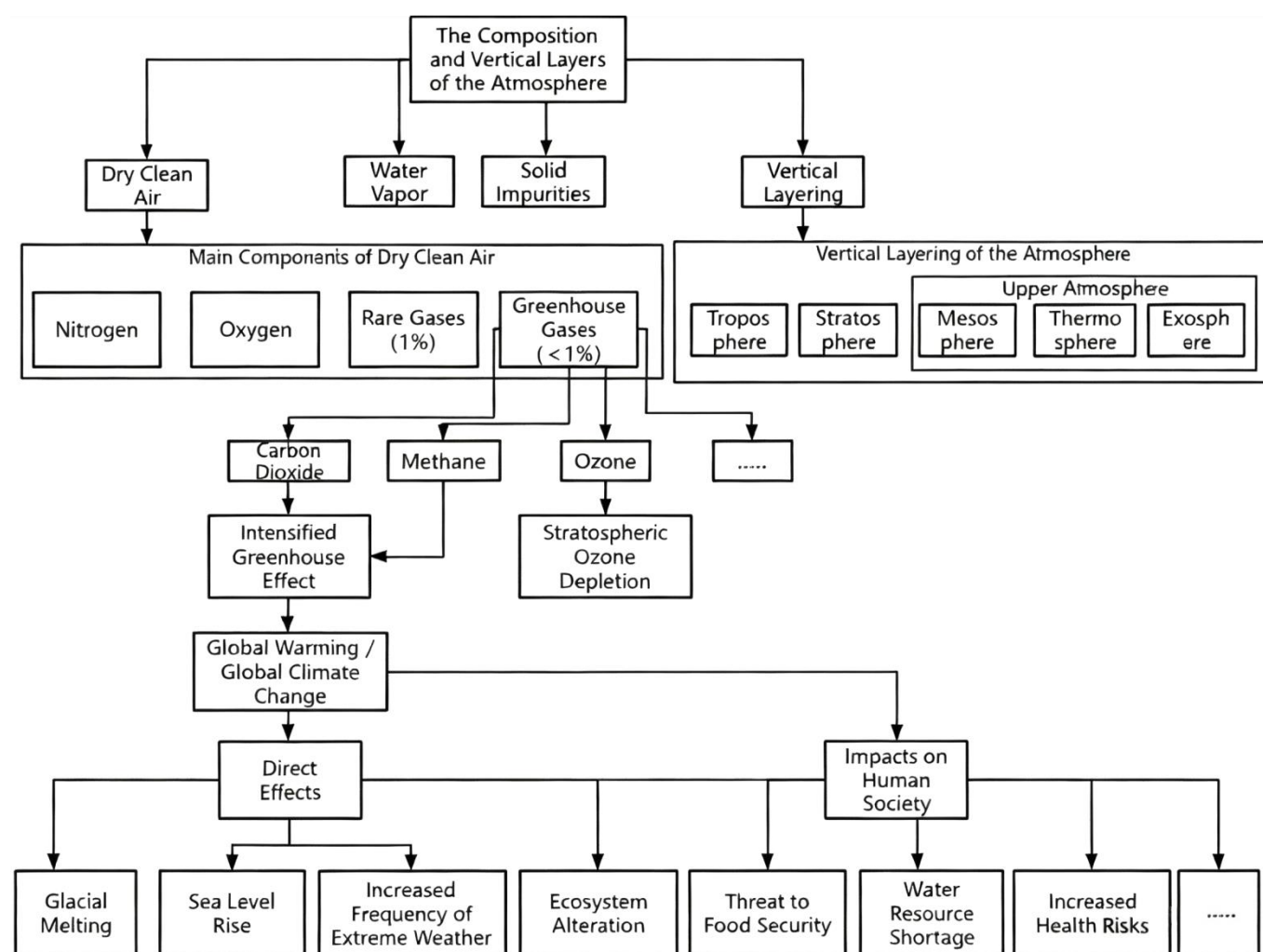


Figure 2. Knowledge Graph of Atmospheric Structure and Climate Change Mechanisms.

4.2. Application Design Based on Behavior Transformation

At the behavioral level, the use of AI tools is based on the ability map to establish clear behavior ladder and development goals, and promote students' climate cognition into sustainable action.

In the current teaching practice, students only stay at the

cognitive level for climate change, do not pay too much attention to their own actions, and lack the motivation for sustained action. In response to such problems, taking the compulsory course "sustainable development" as an example, teachers can design the "21 day low carbon life challenge" activity after teaching, and build a behavior transformation framework based on the ability map (as shown in Figure 3). This activity allows students to input personal life data and generate their carbon footprint visualization report by de-

signing AI carbon footprint calculation agent. The ability map provides clear behavior standards for this purpose, enabling students to quantify the gap between their own behavior and their ideal goals. In the following 21 days, students record their life behavior every day. AI provides them with timely data feedback, positive feedback and personalized low-carbon life suggestions based on the stage goals in the ability map.

Finally, at the end of the activity, the class jointly analyzed the emission reduction data, shared practical insights, deeply understood the significance of individual actions, and promoted the transformation of students' knowledge to practice. Through the behavior guidance of the ability map and the intelligent feedback of AI, students' dilemma of "knowing but not doing" can be effectively solved.

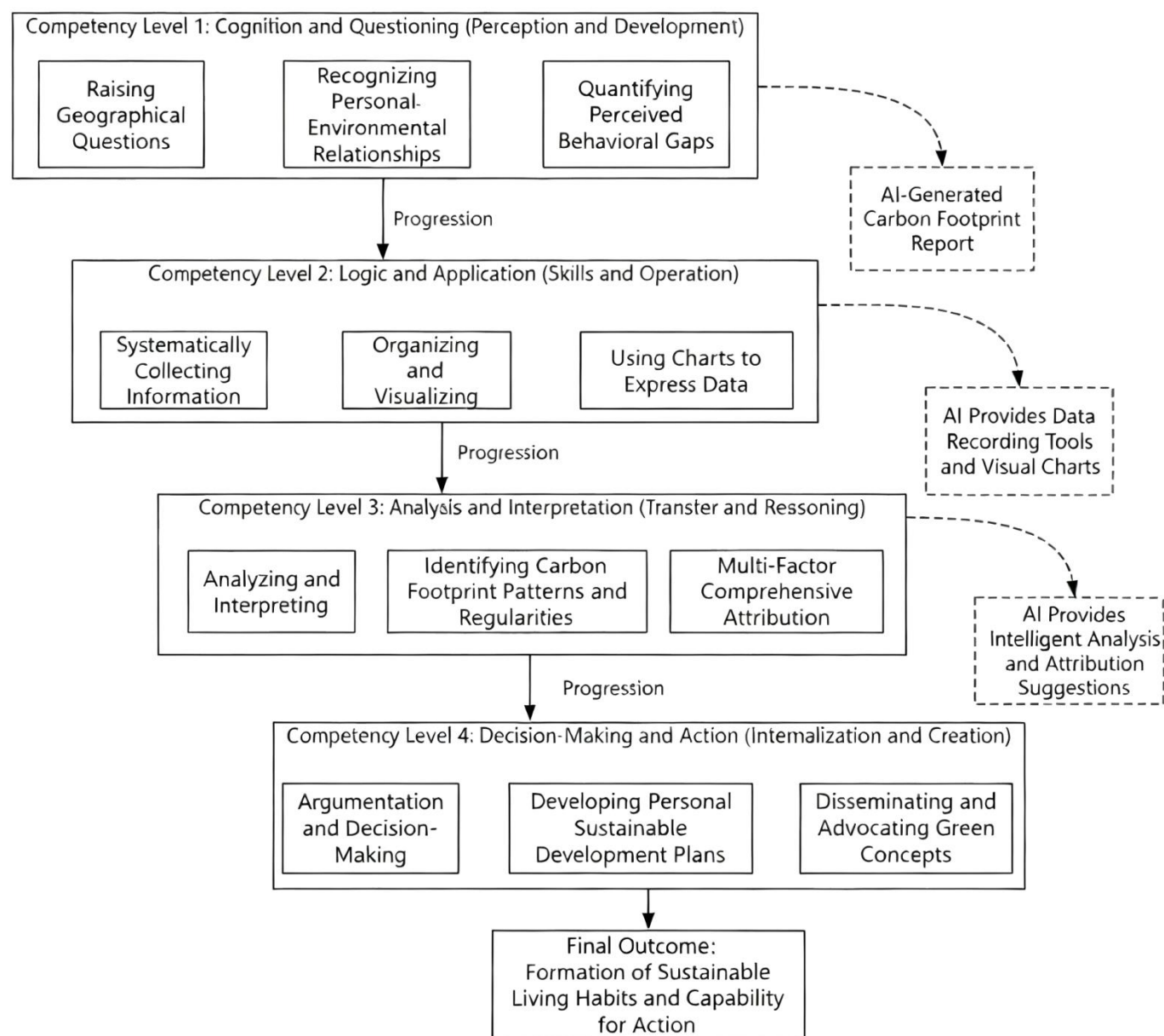


Figure 3. Progression Framework of Students' Geographical Practice Competency Enabled by Artificial Intelligence.

5. Feasibility Analysis and Challenges

The advancement of artificial intelligence (AI) technology has provided robust support for educational innovation. The integration of knowledge graphs and competency graphs,

in particular, offers a systematic instructional scaffold for climate change education in highschool geography. Currently, a wide range of powerful AI tools are openly available to the public, effectively mitigating limitations such as outdated textbook content and a lack of diverse teaching materials. Moreover, the incorporation of "dual graphs" ensures that AI-enabled teaching is not only technological-ly feasible but

also grounded in a solid theoretical foundation. Knowledge graphs can integrate fragmented information into a structured system, while competency graphs clarify behavioral development stages, providing a clear evaluation framework for instruction.

However, the teaching model integrating "dual graphs" with AI still faces multiple challenges in practical implementation.

First, issues related to hardware support and funding remain significant. Although many AI software platforms are available for free use, immersive technologies such as virtual reality (VR) and augmented reality (AR) require equipment that is not yet widely available in most secondary schools, which may partially hinder the achievement of desired teaching outcomes [16].

Second, the implementation of this teaching model places higher demands on teachers' comprehensive competencies. Educators must master multidimensional skills, including graph design, application, AI tool operation, and classroom integration. Additionally, teachers need to place strong emphasis on student privacy protection and ethical issues related to AI tool usage, fulfilling their role as guides and supervisors throughout the process.

Finally, the teaching evaluation system requires further refinement. While AI tools facilitate the construction of knowledge systems and promote behavioral transformation in climate change education, scientifically assessing the internalization of students' cognition, the sustainability of behavioral changes, and the actual effectiveness of such changes remains a critical issue for educators to address.

6. Conclusion

This paper systematically elaborates a dual-driven model centered on knowledge graphs and competency graphs, providing a comprehensive theoretical framework and practical pathway for AI-enabled climate change education in high school geography. The knowledge graph facilitates the integration of fragmented knowledge, promoting the formation of a structured cognitive system among students regarding climate issues. Meanwhile, the competency graph guides the transformation from cognition to practice by delineating behavioral progressions and developmental objectives. AI technologies, through functionalities such as generative dialogue, virtual simulation, and intelligent feedback, effectively bridge the "dual graphs," enabling the synergistic development of cognition and behavior.

The proposed application framework for AI tools offers practical references for frontline teaching. However, challenges related to equipment availability, teacher competency, and evaluation mechanisms may still arise during implementation. Future teaching practices will require educators to enhance their relevant skills and develop multifaceted process-oriented evaluation systems to fully realize the educational value of AI technology in promoting the transition from

knowledge to action in climate change education.

Abbreviations

AI Artificial Intelligence

Author Contributions

Meiyu Li: Conceptualization, Project administration, Writing – original draft

Shengqian Zhang: Supervision, Writing – review & editing

Jiaxin Lu: Writing – review & editing

Data Availability Statement

The data that support the findings of this study can be found at: <https://www.cnki.net/>

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Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Shen, D. D., & He, J. Y. (2019). Progress and Implications of Climate Change Education in Foreign Countries. *Climate Change Research*, 15(6), 704–708.
- [2] Wang, S. D. (2023). Pathways and Characteristics of Youth Participation in Global Climate Change Governance. *China Youth Study*, (6), 24–32. <https://doi.org/10.19633/j.cnki.11-2579/d.2023.0071>
- [3] Opuni-Frimpong, N. Y., Essel, H. B., Opuni-Frimpong, E., & Obeng, E. A. (2022). Sustainable Development Goal for Education: Teachers' Perspectives on Climate Change Education in Senior High Schools (SHS). *Sustainability*, 14(13), 8086. <https://doi.org/10.3390/su14138086>
- [4] Liu, B., Hu, R., & Wang, T. G. (2023). Current Status and Prospects of Big Concept Teaching in Secondary School Geography in China: A Study Based on Bibliometric Analysis and Knowledge Graph Analysis. *Teaching Research*, (18), 1–9.
- [5] Ji, T. T. (2020). The Evolution of Research on Core Literacy in Geography in China: A Keyword-Based Knowledge Graph Analysis. *Teaching Research*, (17), 4–9+61.
- [6] Meng, S. X., & Yang, Q. (2015). Analysis of the Current State of Climate Change Education in High School Geography Teaching in China. *Geography Teaching*, (15), 11–13.

- [7] Duan, Y. X., Chen, B. Y., Li, Y., et al. (2025). Research Progress and Prospects of Geographical Knowledge Graph Reasoning. *Journal of Geo-Information Science*, 27(1), 41–59.
- [8] Zhang, X. Y., Zhang, C. J., Wu, M. G., et al. (2020). A Method for Constructing Geographical Knowledge Graphs Considering Spatiotemporal Characteristics. *Scientia Sinica Informationes*, 50(7), 1019–1032.
- [9] Li, L., & Hu, H. Y. (2025). Cultivating Modeling Competency in the Transition from Junior to Senior High School Physics Teaching: From the Perspective of Knowledge Graph and Problem Graph. *Physics Teaching*, 47(8), 36–39+32.
- [10] Xie, H. (2025). Practical Pathways for Primary School Chinese Reading Teaching from the Perspective of Artificial Intelligence. *Tibet Education*, (6), 12–14.
- [11] Han, W. J., An, N., & Wang, Y. R. (2025). Exploring Practical Pathways for Composition Teaching Based on Generative Artificial Intelligence. *Primary School Teaching (Chinese Version)*, (4), 4–8.
- [12] Zhang, J., Huang, W. F., Wu, C. J., et al. (2025). A Survey on the Construction and Reasoning of Large Model-Enhanced Knowledge Graphs. *Computer Science and Exploration*, 1–21. Retrieved September 17, 2025, from <https://link.cnki.net/urlid/11.5602.TP.20250729.1445.002>
- [13] Ezeudu, S. A., Ezeudu, F. O., & Sampson, M. (2016). Climate Change Awareness and Attitude of Senior Secondary Students in Umuahia Education Zone of Abia State. *International Journal of Research in Humanities and Social Studies*, 3(3), 7–17.
- [14] Wang, X. Q., & Chen, J. (2021). Factors Influencing Climate Change Mitigation Willingness and Behavior Among Adolescents in Coastal China. *Climate Change Research*, 17(2), 212–222.
- [15] Xiang, X., & Meadows, M. E. (2025). Being Proactive About Anthropogenic Environmental Changes: Augmenting Students' Decision Making with Artificial Intelligence (AI) Technology. *Educational Technology Research and Development*. <https://doi.org/10.1007/s11423-025-10523-9>
- [16] Ban, J. (2025). An Analysis of Integrating Artificial Intelligence Education into High School Information Technology Teaching Practice. *Intelligence*, (14), 48–51.