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Geography Education and Earth Science: Bridging Concepts in Chinese High School Teaching

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Abstract: The teaching of earth science in Chinese senior high school geography has faced significant challenges, particularly in the compulsory module "The History of the Earth." Despite being part of the 2019 curriculum reform, current teaching practices often fail to emphasize the geographical nature of the subject, instead treating it as a mix of geology, biology, and historical facts. This paper addresses this challenge by proposing a framework that maintains a geographical focus while teaching earth science concepts. The framework consists of three integrated approaches. First, it introduces a structured method for teaching geological time through an "Eon → Era → Period → Year" progression, helping students build a comprehensive understanding of temporal scales from a geographical perspective. Second, it demonstrates how to effectively use the "Trade Space for Time" method alongside stratigraphic analysis, enabling students to connect spatial and temporal aspects of geographical phenomena. Third, it develops geographical thinking by following the logical pathway of "Fossil → Biology → Environment," ensuring that biological evidence is interpreted within a geographical context. For successful implementation, the paper recommends two key strategies: managing interdisciplinary content while maintaining geography's core focus, and emphasizing geographical characteristics throughout specific teaching content. This approach ensures that "The History of the Earth" fulfills its role in developing students' geographical literacy while contributing to their broader understanding of earth science within China's senior high school curriculum.

Keywords: Earth science education; Senior high school geography; History of the Earth; Teaching objectives; Teaching implementation

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1. Introduction

1.1. Earth science education as a fundamental component of science education

Earth science is a foundational discipline that examines the processes, changes, and interactions within the Earth's system. In contemporary education, the primary goal of science education is to enhance the public's scientific literacy. As part of this broader aim, earth science literacy constitutes a significant aspect of scientific understanding

among citizens [1]. As an important part of the compulsory 1 module of the Chinese high school geography curriculum, earth science plays a significant role in teaching and examination. Earth science education contributes to comprehending the Earth system, recognizing humanity's place in the universe, fostering a balanced perspective on human-environment interactions, and making informed, responsible decisions in public affairs.

1.2. Integration of earth science in high school geography curricula

In primary and secondary education, earth science is primarily taught through science and geography courses. High school geography, in particular, encapsulates themes of the heavens, the Earth, and human interactions. Earth science research has historically evolved from geographical studies, making earth science one of the foundational traditions of geography [2]. The current high school geography curriculum emphasizes earth science education, incorporating topics such as Earth's history and motion. This curriculum effectively integrates earth science principles, ensuring alignment between its content and educational goals, while embedding scientific thinking into geography instruction at the high school level.

1.3. Integrating earth science in senior high school geography to reflect its disciplinary nature

The updated curriculum standards for high school geography emphasize that the "Geography curriculum reflects the nature of the discipline and incorporates geographical thought and methods." Following these standards, the revised high school geography textbooks were officially introduced in 2019. However, in the design and delivery of the compulsory "Geography 1" module, particularly the "History of the Earth" lesson, many teachers fail to adequately emphasize the geographical aspects of the subject. Instead, the teaching approach often lacks a clear geographical focus, resembling lessons in biology or history. To deepen course content, some educators explore topics such as fossils, the characteristics of geological eras, and paleontology, transforming the lesson into a blend of geology, biology, and history. This approach results in students memorizing extensive material without understanding its geographical relevance.

This raises two important questions: What should the key teaching objectives of the "History of the Earth" be? How can teaching methods be designed to fully highlight the geographical nature of the subject and emphasize its unique educational value? This paper seeks to address these questions and contribute to the ongoing discussion.

2. Teaching goal of "The History of the Earth" and emphasis on the nature of geography

Clear learning objectives and logical frameworks enhance students' ability to understand and retain knowledge. According to the 2019 edition of the compulsory Geography textbook for high school, "The History of the Earth" carries significant educational value. It helps students develop an understanding of geological time, examine Earth's history, and cultivate geographical thinking.

2.1. Constructing a cognitive framework of geological time: Eon → Era → Period → Year

Although geological history is addressed in current classroom teaching, the emphasis on its vastness and significance remains insufficient. According to cognitive development theory, students' understanding of abstract concepts like time requires progression from intuitive perception to deeper cognitive construction. Highlighting the grand scale of geological time is therefore essential.

From the perspective of constructivism, individual initiative is a crucial factor in building cognitive structures.

Methods that encourage students to actively participate in this construction process should be further developed [3]. Geography teaching can guide students to independently and collaboratively construct a time cognition system organized as "Eon → Era → Period → Year." This approach enables students to grasp the spatial-temporal logic underlying geological time representation. Engaging in this process not only deepens understanding but also aligns with the core purpose of geography education regarding time concepts.

To summarize, by emphasizing the grand scale of geological time and guiding students in constructing a cognitive framework of "Eon → Era → Period → Year," geography teaching equips students to interpret geological time representations effectively.

2.1.1. Enhancing the unique geographical framework for large-scale time cognition

Reflecting on the "Universe" section covered earlier, geological time and the concept of "eon" are closely linked to the broader study of the universe. The "eon" serves as a foundational unit of time, offering a more detailed perspective within this framework. According to the theory of learning transfer, the likelihood of effective transfer depends on the learner encountering relevant information or skills during the memory retrieval process [4].

The evolutionary history of the universe, connected through the medium of the Sun (discussed in the second section, "The Influence of the Sun on the Earth"), supports students in integrating prior knowledge with current topics. This facilitates learning transfer and gradually refines their understanding of geographical time. Starting with "eon," students can construct a hierarchical time framework of "Eon → Era → Period → Year," emphasizing the logical connections among knowledge points and the disciplinary thinking modes underlying them. This approach aligns with the concept of "powerful knowledge," a term widely recognized in international educational contexts [5].

Geography's perspective on time is distinct from other disciplines. For instance, in physical geography fieldwork, the Quaternary period—a span of geological time often perceived as lengthy—is regarded by geographers as relatively short, even momentary, when considering geomorphic changes, climate evolution, or river development. Such practical examples highlight the relativity of large-scale time in geography. Case-based teaching grounded in real-world observation allows students to grasp abstract concepts through tangible examples, fostering a deeper understanding of the subject matter and strengthening their cognitive framework.

2.1.2. Establishing cognitive connections between time series and geographical processes

The textbook section titled "The History of the Earth" encapsulates geography's perspective on history and time. High school students are already familiar with the concept of "history" through prior learning. In primary school mathematics, they grasped the "year-month-day-hour-minute-second" framework and its quantitative relationships. Additionally, history courses in junior and senior high school introduced them to larger temporal units such as dynasties, eras, and periods, including concepts like the Neolithic Age or the prehistoric period. These frameworks allow students to understand human history in terms of centuries, millennia, or even larger epochs.

However, this foundational knowledge is insufficient for understanding "The History of the Earth" in geography, where time is measured on vastly larger scales. For instance, historian Arnold Toynbee described nations as mere "fragments" of human civilization within a large-scale temporal framework [6]. Similarly, Earth's history represents natural geographical processes that unfold over millions or even billions of years, a scale far beyond that of human civilization.

Teachers can guide students to explore the differences between the time scale of human history and the natural geographical time scale. By using descriptive and interpretative models developed by international scholars, teachers can integrate a problem-oriented approach into the learning process [7]. This approach encourages students to think critically and ask questions. When new knowledge challenges their existing cognitive structures, it stimulates curiosity and a deeper thirst for understanding. Through solving such problems, students gain a clear appreciation of

the distinct educational value of geography as a discipline.

2.1.3. Integrating multiple disciplines to develop a systematic concept of time

In the broader context of senior high school geography education, the curriculum follows systematic geographical frameworks. From the perspective of the discipline's nature—moving from ontology to epistemology—understanding geographical processes with significant temporal characteristics requires students to engage with large time scales. For instance, the evolutionary processes of physical geographical elements, such as living organisms, unfold over durations that far exceed the timescales of human civilization.

From an interdisciplinary teaching perspective, the educational value of geographical time scales serves as a foundational, overarching, and complementary component. Geography courses not only shape students' geographical understanding but also cultivate their broader scientific literacy. Teachers can enhance this through project-based learning, encouraging students to undertake interdisciplinary research projects. By connecting temporal concepts across geography, history, mathematics, and physics, students develop a more integrated understanding of time. For example, students might apply mathematical models to calculate the duration of geographical evolution or use physical principles to explore the relativity of time and space. Such interdisciplinary methods help students form a cohesive concept of time, fostering a deeper appreciation for its complexity and relevance. Additionally, this approach equips students with a temporal awareness that is valuable not only academically but also as informed members of society.

2.2. Investigating the History of the Earth through the "Trade Space for Time" method and stratigraphic structure

There are numerous methods scientists use to study Earth's extensive history. From a geographical perspective, physical geographers typically prioritize the study of strata as their primary research focus. Consequently, when students explore "The History of the Earth," particular attention is given to the method of "Trade Space for Time," which is closely tied to an understanding of stratigraphic structures.

2.2.1. Understanding the relationship between stratigraphic structure and Earth's composition

Strata serve as a key research focus in physical geography, providing a foundational representation of geographical processes and enabling the localized interpretation of natural laws. Physical geography examines the vast spatial field spanning from the sedimentary lithosphere's base to the troposphere's upper boundary. Within this framework, strata form the bedrock of the physical geographical environment, playing an essential role in interpreting the Earth's natural systems.

Strata not only underpin the broader natural environment but also serve as a repository for both natural and human activities. On a macro level, strata constitute a principal component of the lithosphere, reflecting large-scale processes such as plate tectonics. On a micro level, they comprise various chemical elements, illustrating processes like deposition and erosion. Whether examined from the perspective of large-scale tectonic movements or microscopic sedimentary interactions, stratigraphic structures directly mirror Earth's composition and processes.

2.2.2. Combining the "Trade Space for Time" method of stratigraphic structure society

Integrating the "Trade Space for Time" method with stratigraphic study directly supports the development of students' geographical core competencies. By focusing on strata, students simulate geographers' investigative processes, strengthening practical geographical skills. This method also facilitates the transfer of knowledge and thinking. Analyzing stratigraphic phenomena, such as trends and inclinations, helps students connect spatial patterns with temporal processes. This integration enhances their ability to combine time and space perspectives, fostering comprehensive geographical thinking. Overall, the "Trade Space for Time" approach holds substantial methodological value for un-

derstanding the Earth and reconstructing past processes.

2.2.3. Applying the "Trade Space for Time" method in stratigraphic analysis

The "Trade Space for Time" method helps students connect knowledge acquisition with problem-solving by following the pathway of "geographical phenomenon perception → geographical process reasoning → geographical problem-solving." By analyzing formation structures and applying the method, students deduce geographical processes, link spatial characteristics to events, and explore the natural environment's history and development. This reflects the disciplinary paradigm of "pattern and process coupling" and the approach of "explaining the past → describing the present → predicting the future." When students apply their knowledge to real-world problems, they integrate disciplinary thinking with methods. This practical application not only enhances their motivation and sense of achievement but also deepens their understanding of geographical concepts.

2.3. Following the disciplinary logic to develop the geographical thinking path of "Fossil → Biology → Environment"

Studying Earth's evolutionary history through strata involves various approaches, with fossils serving as a key focal point. In addition to fossils, features such as the particle size, distribution, and orientation of rocks within formations also provide valuable evidence. In this context, fossils are emphasized as an essential entry point, enabling students to follow the disciplinary logic and establish the geographical thinking path of "Fossil → Biology → Environment."

To align with the nature of geography as a subject, teaching must guide students to understand and construct the significance of fossils within the discipline. The emphasis on fossils in textbook content reflects the inherent logical framework of geography. Three fundamental premises must be clarified: (1) fossils represent the remains or traces of once-living organisms; (2) biology forms a core component of geographical elements; and (3) the growth and development of organisms are deeply influenced by their geographical environment.

By studying fossils, students enhance their understanding of biological elements and strengthen the foundation for geographical analysis and integrated thinking. Drawing on their prior knowledge from middle school biology, students are already familiar with aspects of biological elements such as physiological structure, respiration, photosynthesis, community dynamics, and density. Fossils, as the remnants of organisms, are also biological elements and should be viewed within this broader framework.

This perspective allows students to not only study living organisms but also consider their remnants, thereby adopting a more comprehensive approach to understanding biological elements. This process reflects the internal logic of "Fossil → Biology → Environment," which illustrates the association mechanism of "geographical elements → geographical environment." This sequence extends from the relationships among biological elements to the broader natural environment.

Developing a geographical understanding of fossils enables students to build effective geographical thinking methods, fostering their ability to analyze connections between organisms and their environments and integrate these insights into the study of natural systems.

3. Key points in implementing "The History of the Earth" teaching with a geographical focus

To emphasize the geographical nature of teaching "The History of the Earth," two key points must be addressed: (1) ensuring an appropriate balance between geography and other disciplines to maintain the integrity of the geography class, and (2) reflecting the core characteristics of geography in the specific teaching content.

3.1. Managing the synergistic relationship between geography and other disciplines

3.1.1. Knowledge organization: Balancing geography with other disciplines

"The History of the Earth" section naturally intersects with fields such as biology and history. Integrating knowledge from multiple disciplines enriches students' understanding, strengthens their knowledge networks, and facilitates the transfer and application of information across subject areas. Geographer Harter noted that in organizing knowledge within systematic geography, it is possible to "seek the principles that govern the distribution in accordance with the systematic science of an element" [8]. Similarly, international scholars have observed that geography incorporates procedural laws from other disciplines to establish its morphological principles [9].

Adolescence is a crucial stage for cognitive and intellectual development. Interdisciplinary approaches during this period promote advanced thinking skills and enhance students' cognitive abilities. From the perspective of knowledge organization, effectively managing the relationship between geography and other disciplines involves actively integrating relevant concepts from biology, history, and other fields. This integration lays a solid foundation for studying Earth's history while maintaining the geographical focus.

3.1.2. Thinking construction: Developing a comprehensive approach through interdisciplinary integration

"The History of the Earth" section can be enriched by incorporating biological evolutionary thinking and historical time-based reasoning. Different disciplines approach real-world problems from unique perspectives: biology focuses on species evolution and ecosystem succession, while history emphasizes the progression of time and periodization.

To maximize the educational value of the geography curriculum, it is essential to not only focus on its internal structure but also connect it to other subject areas. Expanding the curriculum to incorporate interdisciplinary perspectives fosters a broader understanding of human development [10].

Geography's inherently integrative nature complements its associated thinking methods, which also exhibit comprehensive characteristics. By aligning with the approaches of other disciplines, geographical thinking can develop holistic perspectives on various phenomena. This interdisciplinary collaboration allows students to construct more complete and integrated ways of understanding the world.

3.1.3. Conceptual development: Establishing value-based judgment beyond factual knowledge

In teaching the complex content of "The History of the Earth," it is important to consider the psychological principles of memory. Over time, students may forget specific details, such as the Archean, Mesozoic, or Neogene geological ages, their corresponding periods, or even the entire geological time scale. However, the concepts and thinking methods cultivated through deep learning are retained more effectively. This means that while students might not recall precise chronological details years later, they will retain a general understanding of large-scale time divisions, the principles of stratigraphy, and the use of fossil records. These foundational concepts enable them to comprehend Earth's evolution through geological time and apply this knowledge to analyze representative materials. More importantly, this process helps students develop value-based judgments and disciplinary beliefs that extend beyond factual knowledge. Cultivating this conceptual framework fosters lifelong learning and equips students with the intellectual tools needed for continued personal and academic development.

3.2. Key points in teaching implementation based on specific content

3.2.1. Emphasizing the "Earth" component in the Earth surface system

High school students, having already developed their cognitive frameworks, may approach the "Earth History" sec-

tion with preconceived points of interest. The inclusion of the term "history" in the title often shifts their focus toward narratives of the past, potentially framing the content as "science popularization" rather than maintaining a strong focus on the Earth as the subject. As a result, students may concentrate on "history" while overlooking the role and significance of the Earth.

To address this, geography teaching should emphasize the time sequence of "past, present, and future," which aligns with the disciplinary nature of the subject. Teachers must respect students' perspectives and cognitive foundations, using them as logical starting points for instruction. By systematically organizing the content, starting with Earth's cosmic environment and the Sun's influence on Earth, the teaching can guide students from spatial contexts toward understanding Earth itself. This approach establishes a clear framework that ensures the "Earth" remains the central focus of this chapter.

3.2.2. Emphasizing "Geochemistry" as the basis for the geological time scale

Geological knowledge forms a vital part of the geographical knowledge system, with the introduction of "geological time representation" serving as a foundation for subsequent teaching of geological concepts. Students often focus their questions on how different geological ages are defined by the presence of fossils in specific strata. This indicates their interest lies not in memorizing chronological conclusions but in understanding the progressive deepening and development of geographical research processes.

From a teaching perspective, the objective should be to encourage students' active engagement and knowledge construction. Teachers can build on students' cognitive questions to expand and deepen their understanding while maintaining a strong geographical perspective. Emphasizing the geochemical basis for compiling the geological time scale helps students appreciate the physiochemical principles that underpin this framework.

3.2.3. Viewing the evolution process of the geographical environment through the "wholeness" of "The History of the Earth"

The "Evolution of the Earth" is a key topic outlined in the curriculum standards. This content, in the third section of the first chapter of Compulsory 1, serves as the foundation and introduction for high school students studying geography. The textbook presents this topic by following a logical sequence: "the present year → the evolution of Earth's seas and lands → crustal movements → paleontology." It explains the evolution of the geographical environment across major periods, including the Precambrian, Paleozoic, Mesozoic, and Cenozoic eras.

While students gain cognitive memories of specific geological ages through this learning process, their understanding often remains scattered and fragmented. This fragmented approach can lead to an oversight of the holistic characteristics of each age and the overall environment during these periods. To address this, students must integrate and organize knowledge to form a systematic cognitive structure.

As a comprehensive discipline, geography requires students to connect geographical phenomena using integrative thinking. By analyzing the spatial and temporal combinations of geographical elements and utilizing geological time representations, students can develop a more cohesive understanding of Earth's history and the evolution of its geographical environment.

4. Conclusion

Teaching "The History of the Earth" in Chinese high school geography represents a critical opportunity to strengthen students' geographical understanding while maintaining the subject's disciplinary focus. This paper has outlined three key approaches: establishing a clear geological time cognition framework, implementing the "Trade Space for Time"

method, and developing geographical thinking through the "Fossil → Biology → Environment" pathway. These approaches help address the current challenge where teachers often drift away from geographical perspectives when teaching this module.

The successful implementation of these teaching strategies requires a careful balance between geographical focus and interdisciplinary integration. By emphasizing geographical characteristics while incorporating knowledge from related fields, teachers can help students develop a comprehensive understanding of Earth's history from a distinctly geographical perspective. This approach aligns with the 2019 curriculum reform's goals of strengthening disciplinary thinking in geography education.

Looking ahead, there is a need to further develop practical teaching methods that maintain geographical focus while engaging students with complex Earth science concepts. Through proper implementation of the strategies discussed, "The History of the Earth" module can serve its intended purpose: developing students' geographical literacy while building a strong foundation for understanding Earth science. This will ensure that the module achieves its educational objectives within China's senior high school geography curriculum framework.

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