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Research on Senior High School Geography Teaching Based on the Spatiotemporal Coupling Idea—A Case Study of El Niño and La Niña Phenomena

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Abstract: *The spatiotemporal coupling idea—which underscores the intrinsic relationship between the temporal evolution and spatial patterns of geographical phenomena—offers a crucial means of overcoming the fragmented spatiotemporal thinking prevalent in traditional geography instruction. In the context of updated curriculum standards and contemporary global climate concerns, this study employs El Niño and La Niña as a case study. By analyzing the alignment between this content and the spatiotemporal coupling framework, we construct a tripartite analytical model encompassing "spatial differentiation, temporal processes, and factor correlation," and introduce a problem-chain teaching approach for classroom application. Furthermore, we examine the practical challenges of implementing spatiotemporal coupling pedagogy in authentic educational settings and present a comprehensive instructional design. This research aims to furnish actionable theoretical guidance and practical pathways for teaching process-oriented geographical content at the secondary level.*

Keywords: *spatiotemporal coupling; El Niño and La Niña; senior high school geography; problem-chain teaching*

1. Introduction

The General High School Geography Curriculum Standards (2017 Edition, Revised in 2020) stipulates that the module "Fundamentals of Physical Geography" should be organized around the theme of "the impacts of the development and evolutionary processes of natural environmental systems and their constituent factors on human activities" [1]. This requirement calls for teachers to cultivate students' ability to analyze geographical processes from a comprehensive spatiotemporal perspective. As a core concept in geography, spatiotemporal coupling highlights the inherent correspondence and interactive relationship between the temporal sequence of evolution and the spatial distribution pattern of geographical phenomena [2]. It transcends the mere superimposition of time and space, demanding instead that we understand their mutually constraining and co-evolutionary mechanisms from a systemic structural perspective [3]. Integrating the spatiotemporal coupling idea into teaching can effectively help students establish dynamic and systematic geographical thinking, representing a critical pathway for implementing the new curriculum standards.

Existing studies have made progress in teaching strategies, instructional design, and conceptual frameworks. However, most focus on macro-level theoretical interpretations or analyses of general natural processes; few have systematically integrated a spatiotemporal coupling analytical framework with a problem-chain teaching implementation pathway, accompanied by specific classroom cases. These gaps provide both a theoretical reference for this paper and a clear direction for our research.

Current senior high school geography teaching faces prominent difficulties when dealing with such complex process-based content. Relevant surveys indicate that students generally suffer from insufficient prior knowledge, insensitivity to spatiotemporal information in charts and questions, weak capacity for spatiotemporal correlation, and neglect of cumulative temporal effects when analyzing geographical processes [4]. Introducing the spatiotemporal coupling idea into senior high school geography instruction offers an effective way to address these difficulties from the perspective of disciplinary thinking, guiding students to interpret geographical phenomena through the interaction of spatial patterns and temporal processes and to form a systematic, dynamic cognitive framework.

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Notably, the 2025 State of the Global Climate Report released by the World Meteorological Organization shows that 2015 - 2025 witnessed the eleven hottest years on record, the two-year La Niña event has ended, and sea surface temperatures in the central and eastern equatorial Pacific are warming [5]. In early 2026, topics such as "the next two years may become the hottest in history" and "the Earth may face a super El Niño event" aroused widespread public concern. This real-world hotspot builds a bridge between classroom teaching and the outside world, offering vivid, authentic scenarios for geography instruction.

Moreover, El Niño and La Niña phenomena involve chain reactions among multiple factors—including trade winds, ocean currents, sea surface temperature, and atmospheric circulation—with trans-Pacific impacts, which are highly consistent with the spatiotemporal coupling idea. In traditional lectures, teachers often simplify complex causal relationships into conclusive statements such as "floods on the eastern coast and droughts on the western coast." Consequently, students struggle to form a complete causal chain of "abnormal sea surface temperature→trade wind response→circulation restructuring→anomalous climate." The separation of time and space in teaching has become the primary obstacle restricting students' in-depth understanding, representing a typical predicament in current senior high school geography education.

Against this background, and in light of the new curriculum standards and current global climate hotspots, this paper demonstrates the necessity of integrating the spatiotemporal coupling idea into senior high school geography teaching. Taking El Niño and La Niña phenomena as a case study, we analyze the alignment between this content and the spatiotemporal coupling idea, then construct a tripartite comprehensive thinking analysis framework of "spatial differentiation—temporal processes—factor correlation" at the levels of knowledge construction and teaching implementation, and introduce the problem-chain teaching model. We further dissect the practical difficulties in implementing such teaching and finally design a complete classroom teaching scheme as a practical example.

2. Adaptability Analysis of the Spatiotemporal Coupling Idea and Teaching Content

2.1. Connotation of the Spatiotemporal Coupling Idea from a Geographical Perspective

Spatiotemporal coupling is one of the core scientific concepts of geography, referring to the inherent logical correspondence and interactive relationship between the temporal evolution sequence and the spatial distribution pattern of geographical phenomena [2]. It surpasses the simple juxtaposition of time and space implied by spatiotemporal synthesis, emphasizing the nested relationship that "temporal processes drive the remodeling of spatial patterns, while spatial distributions constrain the evolution paths of processes" [3]. From a geographical perspective, the core requirement of spatiotemporal coupling lies in understanding the interlocking relationship between patterns and processes at the structural level: deducing successive temporal evolution from coexisting spatial differentiation, and vice versa. Introducing this idea into senior high school geography teaching requires students to process dual information on temporal processes and spatial patterns simultaneously, constructing a complete cognitive chain that moves from "spatial characteristics" to "temporal processes" and then to "factor correlation."

2.2. Adaptability of El Niño/La Niña Phenomena to the Spatiotemporal Coupling Idea

As typical representatives of the ocean–atmosphere coupling system in the equatorial Pacific, El Niño and La Niña phenomena share high consistency with the spatiotemporal coupling idea, mainly reflected in three aspects:

- Remarkable spatial differentiation: In normal years, a thermal pattern of "warm west and cold east" forms, while abnormal years further amplify the spatial contrast between the eastern and western Pacific. Such distinct comparisons provide students with an intuitive reference frame for establishing regional spatial cognition;
- Complete temporal evolution: Both El Niño and La Niña follow an evolutionary sequence of "triggering—development—maturity—decay." For instance, the super El Niño events of 1997 and 2015 both experienced a full cycle of warm-water eastward migration, weakened trade winds, peak sea surface temperature, and system attenuation, offering clear analytical nodes for students;
- Interwoven multiple factors and prominent cross-scale correlations: The entire process—from abnormal sea surface temperature and trade wind responses to Walker circulation restructuring and

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global climate anomalies—fully reflects cross-scale correlations ranging from local ocean–atmosphere interactions to global teleconnections.

These characteristics are highly consistent with geography's research paradigm of "pattern–process–coupling." Therefore, this content serves as an ideal carrier for teaching that integrates the spatiotemporal coupling idea, as well as high-quality material connecting curriculum standards and real-world hotspots.

3. Innovative Strategies for Integrating the Spatiotemporal Coupling Idea into Teaching

To effectively implement the spatiotemporal coupling idea in classroom teaching, efforts should be made simultaneously in teachers' instructional thinking and students' cognitive construction. We adopt a dual-track strategy: at the knowledge construction level, we establish a comprehensive analysis framework of "spatial differentiation—temporal processes—factor correlation"; at the teaching implementation level, we introduce the problem-chain teaching model.

3.1. Knowledge Construction Level: A Comprehensive Thinking Analysis Framework Based on Spatiotemporal Coupling

We construct a tripartite comprehensive analysis framework of "spatial differentiation—temporal processes—factor correlation" to help students systematically interpret geographical phenomena from three hierarchical dimensions:

- Spatial differentiation: Identify the spatial distribution patterns and regional disparities of geographical objects and phenomena;
- Temporal processes: Sort out the staged changes, evolutionary trends, and cumulative/hysteretic effects of geographical phenomena;
- Factor correlation: Analyze the causal interactions and feedback relationships among various factors.

The selection of these three dimensions follows the progressive cognitive law of geographical comprehensive thinking: spatial differentiation is the starting point for phenomenon identification, temporal processes are the core of mechanism exploration, and factor correlation is the destination of systematic synthesis. This progressive analytical logic provides a clear reasoning path for the comparative teaching of the three states (normal, El Niño, La Niña) shown in Table 1.

Table 1: Comprehensive Knowledge Analysis Framework for Teaching El Niño and La Niña Phenomena.

State Dimension	Spatial Differentiation	Temporal Process	Factor Correlation
Normal Year	Pattern: Warm west and cold east; contrasting wet and dry conditions in the east and west. Circulation: Driven by trade winds, the Walker circulation remains stable.	The system maintains a stable equilibrium: trade winds push warm water westward, while cold water upwells in the east for compensation.	Stable Walker circulation; cold-water upwelling brings abundant nutrients, supporting prosperous fisheries along the Peruvian coast.
El Niño Year	Pattern: Reversed; the eastern coast turns wet and the western coast turns dry. Circulation: The Walker circulation weakens or even reverses.	Trigger: Weakened trade winds drive warm water eastward. Development: The thermocline deepens and sea surface temperature rises. Maturity: Large-scale abnormal warm-water zones form. Decay: Trade winds recover and the system returns to equilibrium.	Triggers global chain reactions: droughts in Australia and Indonesia, floods in South America. Impacts on China: prone to "floods in the south and droughts in the north"; fewer typhoons.

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La Niña Year	Pattern: Intensified; the eastern coast becomes drier and the western coast wetter. Circulation: The Walker circulation strengthens significantly.	Trigger: Abnormally intensified trade winds. Development: Cold-water upwelling strengthens. Maturity: Circulation becomes extremely active. Decay: Trade winds subside and the system transitions back to equilibrium.	Impacts generally opposite to El Niño: heavy rainfall in Southeast Asia and aggravated drought in South America. Impacts on China: prone to "floods in the north and droughts in the south"; more typhoons.

Table 1 juxtaposes the three states to form a spatiotemporal comparative sequence of "normal—El Niño—La Niña." The normal year serves as the baseline reference, while El Niño and La Niña respectively demonstrate two evolutionary directions—the reversal and intensification of spatial patterns. Together, they reflect the complete cognitive progression from spatial differentiation identification and temporal process tracking to factor correlation analysis.

3.2. Teaching Implementation Level: Introduction of the Problem-Chain Teaching Model

After clarifying the knowledge analysis framework based on spatiotemporal coupling, transforming it into practical classroom practice is the key to teaching success. We introduce the problem-chain teaching model as the core implementation strategy.

"A problem chain refers to a set of hierarchically structured, systematically connected teaching questions transformed from textbook content by teachers to achieve specific teaching objectives on the basis of students' prior knowledge and experience; these questions center on the core theme, relatively independent yet interrelated with one another" [6]. Its core value lies in guiding students to explore the essence of knowledge along a preset cognitive path from shallow to deep and from surface to interior, realizing progressive thinking development.

Introducing the problem chain into spatiotemporal coupling teaching in this research has three specific advantages:

First, the problem chain builds a bridge between the analysis framework and classroom practice, guiding students to follow the logical path of "spatial differentiation—temporal processes—factor correlation," thus converting the analytical logic of spatiotemporal coupling into operable teaching carriers.

Second, questions stimulate students' inquiry interest, particularly through cognitive conflicts (e.g., "penguins on the equator") that spark curiosity and shift students from passive reception to active exploration.

Third, the well-organized design of the problem chain facilitates progressive thinking development. This orderliness is reflected in two aspects: progressive knowledge logic (from simple to complex, from phenomena to essence, from local to global) and progressive thinking hierarchy (from known to unknown, from memorization and comprehension to analysis and evaluation). Such design provides learning scaffolds for students to gradually overcome cognitive barriers and elevate their thinking levels.

In this research, the problem chain revolves around the core causal logic of "abnormal sea surface temperature→trade wind response→circulation restructuring→anomalous climate" and runs throughout the entire classroom teaching process, serving as a vital link connecting teachers' instruction and students' learning.

4. Practical Difficulties in Implementing Spatiotemporal Coupling Teaching

Although the spatiotemporal coupling idea and the problem-chain model provide a clear theoretical framework for teaching, teachers still face multiple challenges in on-site classroom implementation. Identifying these difficulties and proposing corresponding coping strategies is a prerequisite for effective instructional design execution.

4.1. Abstract Representation and High Cognitive Threshold

El Niño and La Niña phenomena involve abstract concepts such as the Walker circulation,

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thermocline, and positive feedback, and the invisible ocean–atmosphere interaction processes cannot be observed directly. Students tend merely to memorize conclusions such as "increased precipitation along the eastern coast during El Niño years," yet fail to understand the internal mechanism of "how weakened trade winds trigger circulation restructuring." They remain at the memorization level rather than reaching causal reasoning.

4.2. Cognitive Bias Regarding Time Scales

Time is at the heart of geographical processes. However, in teaching, students often focus only on the anomalous state itself while neglecting differences across various stages of the process. For example, the warming effect of El Niño usually peaks in the subsequent year, yet students tend to directly correlate abnormal sea surface temperature in a given year with climate disasters occurring in the same year. This cognitive tendency of neglecting cumulative temporal effects causes spatiotemporal coupling teaching to devolve into static spatial comparisons [4].

4.3. Broken Connections across Multiple Scales

El Niño and La Niña exert global impacts, linking local abnormal sea surface temperature to extreme events thousands of miles away via atmospheric teleconnections. Nevertheless, students usually focus on changes within a single region and struggle to establish multi-scale correlations among "the equatorial Pacific, Asian monsoon regions, and southern China," resulting in breaks in their thinking logic.

5. Practical Difficulties in Implementing Spatiotemporal Coupling Teaching

Targeting the above difficulties, this section designs a complete classroom teaching scheme in accordance with the theoretical framework constructed above (Table 2). Centered on progressive serial questions forming a problem chain, this design runs through all classroom procedures, sequentially covering the three dimensions of spatial differentiation, temporal processes, and factor correlation, and clarifies targeted strategies to break through corresponding difficulties in each session.

Table 2: Classroom Teaching Design of El Niño and La Niña Based on the Spatiotemporal Coupling Idea.

Teaching Session	Teacher Activities & Scenario Creation	Student Activities	Problem Chain	Design Intent
Pre-class Preview	Assign preview tasks: ① Read textbook content on the Walker circulation; ② Observe the Equatorial Pacific Sea Surface Temperature Distribution Map and consider "why there exist east–west climate disparities along both sides of the equator"; ③ Complete preview quizzes on basic knowledge of pressure belts, wind belts, and thermal circulation. Collect preview data to diagnose students' cognitive starting points.	Read textbooks, observe maps, finish preview quizzes, and record questions.	(Preliminary questions): Solar radiation near the equator is similar on both sides; why do tropical rainforests prevail along the western Pacific coast while arid deserts dominate the eastern Pacific coast?	Activate prior knowledge of pressure belts, wind belts, and thermal circulation; initially establish spatial cognition of "east–west disparities"; expose students' cognitive starting points.
Lesson Introduction	Present images and videos of Galápagos penguins, introduce	Observe and reflect, generate	Question 1 (Spatial Differentiation):	Trigger cognitive conflict using the counterintuitive

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	them as the only penguin species living near the equator, and raise the follow-up question: "Preview materials indicate low water temperatures in the eastern Pacific; how does this relate to the living environment of penguins?"	cognitive conflicts, and attempt explanations drawing on preview knowledge.	Why do penguins live near the equator? What water temperature and climatic characteristics of this sea area does this reflect?	presence of equatorial penguins, prompting students to trace internal causes from abnormal spatial patterns and initially build awareness of spatiotemporal correlations.
New Lecture (I): Normal Years	Present a location diagram of the eastern and western Pacific coasts, assign the task: "Draw the Walker circulation on the diagram based on thermal circulation principles." Patrol students' drawing work and display typical drafts.	Cooperate in groups to draw schematic diagrams of the Walker circulation and elaborate on them.	Question 2 (Temporal Process + Factor Correlation): Draw the Walker circulation according to thermal circulation principles and explain why the spatial pattern of "warm west and cold east" can sustain long-term stability.	Combine static spatial patterns with dynamic sustaining processes through drawing and elaboration, revealing the coupling essence that "spatial patterns are driven by temporal processes."
New Lecture (II): El Niño Years	Present data of the 1982–1983 super El Niño event: sea surface temperature in the eastern Pacific rose by nearly 5 ℃, Peruvian anchovy catches plummeted, global soybean prices surged, and poultry prices climbed. Provide a fill-in causal chain diagram (Abnormal sea surface temperature → ? → Reduced anchovy stocks → ? → Rising soybean meal prices → ? → Higher poultry prices) and require students to complete intermediate links.	Read materials, discuss in groups and finish the causal chain diagram.	Question 3 (Temporal Process + Spatial Differentiation): After trade winds weaken, how do spatial patterns on the eastern and western sides change? Draw the Walker circulation under this condition.	Guide students to shift from the baseline normal state to dynamic abnormal states, realizing the cognitive leap from static spatial recognition to deduction of spatiotemporal evolution. The fill-in diagram lowers the threshold for causal reasoning.
	Follow-up question: "Why can fishermen not catch fish? Why do chicken prices rise in supermarkets?" Organize groups to display reasoning results of the causal chain.	Group representatives present reasoning outcomes of the causal chain.	Question 4 (Factor Correlation): How does the causal chain transmit from reduced fisheries to rising prices of terminal	Train students to conduct reasoning on chained multi-factor causality, understand the systematic feature of "one factor triggering chain reactions", and

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			consumer goods? What characteristic of the geographical environment does this reflect?	strengthen analytical capacity for factor correlations.
	Present statistical graphs of precipitation anomalies in eastern China during El Niño years from 1951 to 2023.	Analyze graphs and infer corresponding impacts on China based on acquired knowledge.	Question 5 (Factor Correlation): What abnormal climatic conditions may eastern China face during El Niño years? Analyze their formation mechanisms.	Lead students to complete multi-scale correlations ranging from local ocean-atmosphere interactions to climatic responses in China, cultivating comprehensive cross-scale analytical capabilities.
New Lecture (III): La Niña Years	Present news materials on the 2008 La Niña event that induced low-temperature snow disasters in southern China. Assign the task: "Imitate the analytical method used for El Niño years; work in groups to independently complete an analysis table for La Niña years (covering spatial patterns, Walker circulation, causal chains and impacts on China)."	Collaborate in groups to independently finish the La Niña analysis table and draw diagrams of the Walker circulation.	Question 6 (Spatial Differentiation): Does La Niña represent a regression or intensification of the "warm west and cold east" pattern?	Test students' mastery of core causal logic through independent inquiry and comparative analysis, cultivating knowledge transfer and analogical reasoning abilities.
	Organize group presentations and guide discussions comparing similarities and differences between El Niño and La Niña.	Display analytical outcomes and participate in comparative discussions.	Question 7 (Factor Correlation + Temporal Process): Compared with El Niño, how do trade winds and circulation differ during La Niña years?	Reinforce the core causal chain of "abnormal sea surface temperature → trade wind response → circulation restructuring → abnormal climate" via comparative analysis.
	Present schematic diagrams linking the 2008 southern China ice-snow disasters to La Niña.	Analyze diagrams and independently interpret correlation mechanisms.	Question 8 (Factor Correlation): How does the La Niña event thousands of miles away in the Pacific evolve into a "Spring Festival travel crisis" in China?	Strengthen multi-scale correlations and regional comparative analytical capacity through differentiated responses of the same region (China) to two distinct phenomena

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			How do its impacts differ from El Niño?	(El Niño/La Niña).
Consolidation & Improvement	Present unlabeled equatorial Pacific sea surface temperature anomaly maps and corresponding climate statistical graphs of China for the same year.	Identify the climatic state (normal/El Niño/La Niña), state judgment criteria verbally, and analyze formation mechanisms of the illustrated climate anomalies.	Variant Question: Which climatic state does the year shown in the diagram belong to? What are your judgment criteria?	Evaluate students' comprehensive ability to deduce temporal process states from abnormal spatial patterns and analyze factor correlations, and instantly test the achievement of teaching objectives.
Lesson Summary	Organize groups to draw mind maps with core clues: "Abnormal sea surface temperature → trade wind response → circulation restructuring → abnormal climate". Patrol and offer guidance, select excellent works for display and comments.	Draw comprehensive mind maps covering the three states centered on the core causal chain.	Core Clue Question: Illustrate differences in the causal logic of "sea surface temperature – trade winds – circulation – climate" under the three states using arrows and keywords.	Integrate scattered knowledge of the three states into structured cognition via mind maps anchored to the core causal chain, helping students solidify the analytical path of spatiotemporal coupling through comparative analysis.
After-class Assignment	Assign the task: "Formulate a household climate risk response proposal (no less than 300 words) for both El Niño and La Niña scenarios respectively, and elaborate on scientific foundations."	Access reference materials and propose response suggestions separately for the two scenarios.	Extended Question: What preparations should families make if an El Niño event occurs next year? What about La Niña?	Transfer classroom knowledge to real-life scenarios, exercise predictive and decision-making capacities based on scientific reasoning, transform cognition into responsible actions, and implement the concept of human-land coordination.

6. Conclusion

The spatiotemporal coupling idea addresses the core problem of separated time and space in traditional geography teaching, serving as an important pathway for implementing geographical core competencies. Taking El Niño and La Niña phenomena as a case study, we construct a comprehensive thinking analysis framework of "spatial differentiation—temporal processes—factor correlation," introduce the problem-chain teaching model, and provide a complete classroom teaching design. This approach connects the full cognitive chain—from spatial pattern identification and temporal process deduction to comprehensive factor correlation analysis—helping students improve their comprehensive thinking capacity for complex geographical processes and offering operable references for teaching

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process-oriented geography content in senior high schools.

Future research can be deepened in three dimensions: (1) in terms of teaching content, explore typical materials suitable for spatiotemporal coupling analysis across various modules to promote deeper integration of this idea with more chapters; (2) in terms of teaching methods, build visualized classrooms combining GIS, digital Earth, and other technologies, and popularize project-based and inquiry-based learning; (3) in terms of teaching evaluation, establish a diversified evaluation system and develop special evaluation indicators targeting the proficiency of spatiotemporal comprehensive thinking. Coordinated progress in these three dimensions will facilitate the practical implementation of spatiotemporal coupling thinking in classrooms and provide long-term support for cultivating students' comprehensive thinking and global vision.

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