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Deep Learning of Geographic Concepts from the Perspective of APOS Theory—The Water Cycle as an Example

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Abstract: Geographic concepts are at the core of the geographic knowledge system, and realizing the deep learning of geographic concepts is an important goal of today's geography classroom teaching. This paper takes the inextricable link between APOS theory (four stages of the learning process) and deep learning as the starting point, and describes how to utilize APOS theory to carry out deep learning of geographic concepts. It aims to promote the innovation of geography teaching mode to meet the current needs of educational development.

1. Introduction

Geographic concepts are the understanding of the essential attributes of geographic things, is an abstract summary of the essential characteristics of various geographic phenomena, is to build the cornerstone of the knowledge system of geographic disciplines. How to guide students to learn geographic concepts vividly and creatively? How to cultivate students' ability of independent learning and cooperative inquiry in the process of learning geographic concepts? How to effectively carry out in-depth learning of geographic concepts so as to explore the geographic concepts of more nurturing value? These issues have become the focus of attention of geography educators. Based on the APOS theory of cognitive psychology, effective progress has been made in the teaching of concepts in many disciplines, so this paper takes the water cycle, an important concept in geography, as an example, and tries to introduce the APOS theory into the teaching of geography concepts, in order to provide some references for geography educators when they face the above problems.

2. APOS Theory and Deep Learning of Geographic Concepts

2.1 APOS theory

In the late 1980s and early 1990s, the American educator Dubinsky carried out an in-depth study of Piaget's theory of "self-reflexive abstraction", further refined it, and put forward the theory of APOS in conceptual teaching. He divided the conceptual learning process into four stages: Action,

Process, Object and Scheme, and chose the first letter of the word, hence the name APOS theory.[1]

In the Action stage, the teacher creates a situation according to the students' pre-concepts, stimulates the students' interest in learning geographic concepts, arouses the students' intentional attention to learning geographic concepts, and guides the students to have a preliminary perception of the new concepts. In the Process stage, teachers need to organize students to explore the concept. Through students' independent inquiry, a general understanding of the new concept is constructed in their minds. In the Object stage, students need to further clarify and compress their understanding of the concepts on the basis of the process, regard the concepts as a whole, and flexibly apply the concepts to solve practical problems. In the Scheme stage, students need to review the formation process of concepts in the Activity, Object, and Process stages, and integrate old and new concepts to form a geographic conceptual network.[2]

2.2 Deep learning of geographical concepts

The concept of deep and shallow learning was first introduced in 1976 when American scholars Ference Marton and Roger Saljo categorized learners into deep level processors and shallow level processors based on the way they acquired and processed the information[3] .

Shallow learning usually refers to the surface-level understanding of geographic concepts, including the sketching of key information, the identification of similar concepts, and rote memorization. This kind of learning is usually mechanical, and it is difficult to go deeper into the perspective of knowledge generation to understand and analyze geographic concepts. If conceptual teaching only stays at the shallow learning stage, the nurturing value of geography can hardly be fully realized, and students' geographic core literacy can hardly be effectively cultivated.[4] The core qualities of students in geography can hardly be effectively cultivated.

As opposed to shallow learning of geographic concepts, deep learning is an understanding-based learning in which learners actively and critically learn geographic knowledge and ideas with the goal of developing higher-order thinking and solving practical geographic problems with integrated geographic knowledge and incorporate them into their original cognitive structures, so that they can transfer them to other knowledge situations as they wish[5] .

3. Interrelationship between APOS theory and deep learning of geographical concepts

3.1 APOS theory as a pathway to deep learning of geographic concepts

To realize the deep learning of geographic concepts, an important issue to consider is how to guide the learners to gradually transition from low-order thinking to high-order thinking in the process of learning geographic concepts, so as to realize the transfer of knowledge and application and the sublimation of affective attitudes and values after the acquisition of knowledge.The APOS theory answers this question, describing the process of students' gradual thinking in depth from the viewpoint of cognitive psychology. Starting from the conceptual perception in the operation stage, it gradually transitions to the conceptual exploration in the process stage, then to the conceptual mastery in the object stage, and finally to the formation of conceptual network in the illustration stage.

3.2 Deep learning is the goal pursued by the APOS theory

In terms of the essence of the two, APOS theory reveals the cognitive process of students' learning concepts, and deep learning emphasizes that students not only need to deeply understand knowledge, but also need to obtain multiple aspects of development in addition to knowledge through learning. However, the pursuit of knowledge is ultimately for the overall development of human beings. In this

sense, deep learning can be regarded as the natural extension and ultimate goal of APOS theory, which pushes the process of cognitive development to a higher level of self-actualization and continuous growth.

4. Principles of deep learning of high school geography concepts based on APOS theory

4.1 Respect for the subjectivity of students

Students are the main body of learning geographic concepts. Ensuring students' subject position in the learning process is a prerequisite for realizing deep learning, and is also a basic requirement of APOS theory. Before carrying out teaching activities of geographic concepts, teachers should have a deep understanding of students, design prior organizers based on students' existing knowledge and life experience, so that teaching can be built as much as possible on the students' existing stage, rather than hanging in the air.

4.2 Emphasizing the generative nature of teaching and learning

Although APOS theory divides the stages of teaching and learning into four phases and develops a detailed description of each phase, it does not model teaching and learning activities in this way. On the contrary, it attaches great importance to the generativity of the teaching process in its application. Teachers should combine the APOS theory with the reality in the process of teaching design and implementation, so as to present targeted, class-specific and student-specific teaching.

4.3 Apply to moderately abstract content

APOS theory and deep learning are not appropriate for all content; only content that is more abstract and difficult for students to understand is applicable to APOS theory and deep learning. This is because content with a higher level of abstraction and a higher difficulty factor can support deeper thinking. In contrast, simple and intuitive content can be easily accessed by students with lower-order thinking, and if the teacher forcefully adopts APOS theory to design teaching activities, it will make students feel that the course is long and boring, which is counterproductive.

5. Pedagogical Applications of Deep Learning of Geographical Concepts Based on APOS Theory

In order to give you a clearer understanding of the application of APOS theory in deep learning of geography concepts, this paper takes "water cycle" as an example to demonstrate the teaching application of deep learning of geography concepts based on APOS theory.

5.1 Pedagogical objectives

From the viewpoint of basic learning conditions, after the accumulation of daily life experience, students have a relatively deep understanding of the existence of water in nature and the conditions of transformation. So they have a certain understanding of the links of the water cycle, but lack the conceptual knowledge of the scientific system. Based on this, the teaching objectives of this lesson are shown in Table 1.

Table 1: Teaching objectives of the water cycle.

Geographic Practicality	Conducting water cycle simulation experiments to develop the awareness and ability of scientific inquiry. Flexibly apply the principle of the water cycle to analyze the causes of waterlogging in a city and propose corresponding measures to solve the problem. Understand the concept of the water cycle from the perspective of the interconnectedness of the various links, and draw a sketch of the water cycle.
Regional Cognition integrated thinking	Accurately describe the links and processes of the three major water cycles, incorporating regional information. Geographic significance of the water cycle with examples.
Human Terrain Perspective	Learning the process of water cycle, understanding the significance of water cycle, appreciating the mutual influence of water cycle and human activities, and establishing the scientific concept of water use.

5.2 Teaching and learning process

5.2.1 Activity stage - initial perception of concepts

The activity stage is the beginning stage for students to learn geography concepts and the preparation stage for deep learning. In this stage, teachers need to create a good atmosphere for students. Teachers start from the students' existing life experience and introduce the concept in a pleasant way in order to arouse the students' interest in learning, arouse their intentional attention, and prepare for the emotional and cognitive preparation for deep learning of geography concepts. Simply put, by letting students feel the contextual background related to the concept, the teacher triggers the conflict between the old knowledge and the new knowledge, thus stimulating the desire to explore, and taking the opportunity to build a solid point of linking the new knowledge in the mind.

Activity 1. The teacher plays a video of the spectacular sight of a big river entering the sea and asks students to watch and think about why the sea water does not increase or decrease when a hundred rivers return to the sea. This question is challenging, so the teacher can guide thinking through the following chain of questions. What forms does water exist in nature? Where does water from rivers come from? Where does rainwater come from? How are clouds formed?

Design Note: Teachers start from the students' existing, but not deep thinking of geography, create a problem situation, triggering cognitive conflict, so as to stimulate students' interest in learning. In the process of thinking about the problem and searching for the answer, students perceive the conceptual background of "water in nature is in a cyclic state, not consumed and then produced again like electricity". At the same time, through the magnificent natural scenery, students develop the ability to feel the beauty and appreciate the beauty.

5.2.2 Process stage - gradual internalization of concepts

The process stage is a key stage in students' learning of geographical concepts and is the entry stage for deeper learning. Students use the conceptual background acquired in the activity stage as the basis for further inquiry activities. In the inquiry activities, students are engaged in observation, comparison, analysis and other thinking operations, which can effectively promote the internalization of concepts and the formation of new cognitive structures. However, it should be noted that students' inquiry activities are prone to encounter obstacles, so teachers should give timely help, but need to grasp the strength, otherwise the students' research activities will lose their meaning.

Activity 1. The teacher conducts a water cycle simulation experiment. The experiment is divided into three groups, during which the teacher invites students to participate together. Internal circulation in the sea: Pour an appropriate amount of hot water into a basin and place it in a glass box. As shown in Figure 1. Internal circulation on land: Pour an appropriate amount of hot water into a bowl and place it in a basin to simulate waters on land. Fill other areas of the basin with soil to simulate land. Next cover it all with a glass box. As shown in Figure 2. Cycle between land and sea: Pour an appropriate amount of hot water into a cup to simulate an ocean. Fill another cup with sand to simulate land that is prone to seepage and place it to the left of the hot water cup. Prepare a slope and place it on the right side of the hot water cup and align the bottom of the slope with the mouth of the hot water cup to simulate land that is not easily permeable, and then cover it all with a glass box. This is shown in Figure 3.

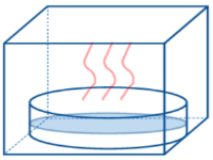

Figure 1: Schematic diagram of the offshore internal circulation simulation experiment

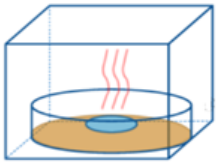

Figure 2: Schematic diagram of the onshore internal circulation simulation experiment

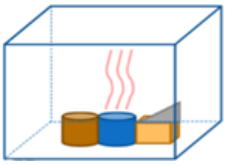

Figure 3: Schematic diagram of the inter-sea and land circulation simulation experiment

At the end of each experiment, the teacher asks students to describe what they saw during the experiment. Through the students' descriptions and the simulation of the experiment, the teacher illuminates the main parts of the water cycle (evaporation, water vapor transport, rainfall, infiltration, surface runoff, subsurface runoff), as well as the types (internal circulation of seawater, internal circulation of land, and inter-oceanic and inter-land circulation).

Design Note: Through the simulation experiment, the teacher narrows down the water cycle, which is majestic in nature and difficult to get a glimpse of the whole picture, between the podium, so as to facilitate the students to explore the types, links and processes of the water cycle. Through the simulation experiment, students gradually enter into a deeper study of geographic concepts as they understand the general process of the water cycle and grasp the types of the water cycle and the main links involved. This paves the cognitive way for the object stage to learn the specific process and geographic significance of the water cycle in depth. In addition, through geography simulation experiments, students' geography practicality has been effectively practiced.

5.2.3 Object stage - simplified compression of concepts

The object stage is an important stage for students to learn geographic concepts, and it is the stage of deep learning in progress. In the process stage, although the cognition formed in the students' minds has touched the essence of the concepts, in the students' minds, the cognition at this time is vague,

rough and lengthy. Therefore, in the object stage it is necessary to further concise and clarify the cognition gained in the process stage. In order to achieve this, the teacher can guide the students to use various concise symbols to characterize the concepts learned, such as tables and signal outline diagrams.

Activity 1: The teacher presents a video on the formation process of summer storms at sea and a simulation animation of the internal circulation at sea. Students are invited to watch and discuss the video, and then select a representative to act as a temporary classroom teacher to explain the process of the internal circulation at sea, and at the same time draw a sketch of the internal circulation at sea.

Activity 2: The teacher will present an animation of the simulation of the internal terrestrial cycle and a sketch of the environment of an inland region. After watching the animation, the students will be asked to introduce the process of the internal terrestrial cycle in the region according to the environmental sketch, and to draw a sketch of the internal terrestrial cycle. It is worth noting that in this link, students are prone to ignore the transpiration of plants, the teacher needs to make the necessary additions to this, you can present a lively and interesting science video, you can also carry out a small experiment, such as a clean plastic bag wrapped around the vegetables, you can observe the formation of water mist on the plastic bag.

Activity 3: The teacher presents a simulation animation of the cycle between land and sea and a case study of the water cycle in a coastal city, then divides the students into several learning groups and asks the group members to describe their own cycle between land and sea, assuming that they are a drop of water in the local area according to the animation and the case study. After the group discussion, send a representative to describe the process of water cycle between sea and land, and draw a corresponding water cycle sketch.

Design Note: The teacher presents the learning materials in order from easy to difficult, and in the process of learning, guides students to rationally apply the learning materials for conceptual inquiry. At the same time, the drawing of geographic sketches helps students to clarify and simplify geographic concepts, so that students can easily memorize the specific aspects of the water cycle, and can regard each type of water cycle as a whole object, so that they can process the information in a larger unit to solve related problems. In addition, in the process of conducting regional case studies, students discussed and inspired each other, and their regional cognition and integrated thinking were also cultivated.

Activity 4. The teacher asks students to imagine how the world would change without the water cycle. After students brainstorm, the teacher then presents the case:① The Yellow River and the thousands of ravines of the Loess Plateau② The Yangtze River flows eastward into the sea without drying up.③ At the mouth of the Yangtze River there is China's largest fishing ground - Zhoushan Fishing Ground④ The Murmansk Frozen Harbor formed by the Atlantic warm current. Under the guidance of the teacher, students can easily reason out the main geographical significance of the water cycle through these cases.

Design Note: Instead of presenting the geographical significance of the water cycle directly, the teacher lets the students play with their imagination, taking the opportunity to train students' divergent thinking, cultivate their innovative ability and enhance the educative value of this lesson. Then students are guided to reason out the geographical significance of the water cycle through specific cases. On the one hand, the combination of the theorized significance and realistic cases, i.e., vivid image and mutual corroboration, is highly persuasive and conducive to students' understanding and acceptance. On the other hand, students need to regard the water cycle as a whole object in the process of analyzing the case, thus further consolidating their learning of the water cycle process and ensuring that they meet the requirements of the object stage. The whole process is essentially an in-depth learning of geographical concepts.

5.2.4 Scheme stage - conceptual network formation

The schema stage is the target stage for students to learn geographic concepts, and it is the stage of reaching deep learning. Through the previous stages of learning, students have a relatively deep understanding of the background, connotation and meaning of the concepts. Based on this, what the teacher needs to do in the schematic stage is to guide students to systematically sort out and integrate the concepts they have learned, so as to help students form a complete conceptual framework and achieve the purpose of systematizing geographic knowledge. Finally, the teacher can also use comprehensive geography problems to observe whether students can apply the concepts comprehensively to test whether they have reached the illustration stage to complete the depth of conceptual learning.

Activity 1. The teacher guides the students to map the conceptual structure of the lesson in conjunction with the water cycle schematic and invites the students to present it on the stage as shown in Figure 4 below. If students have any gaps, the teacher will take care to add them.

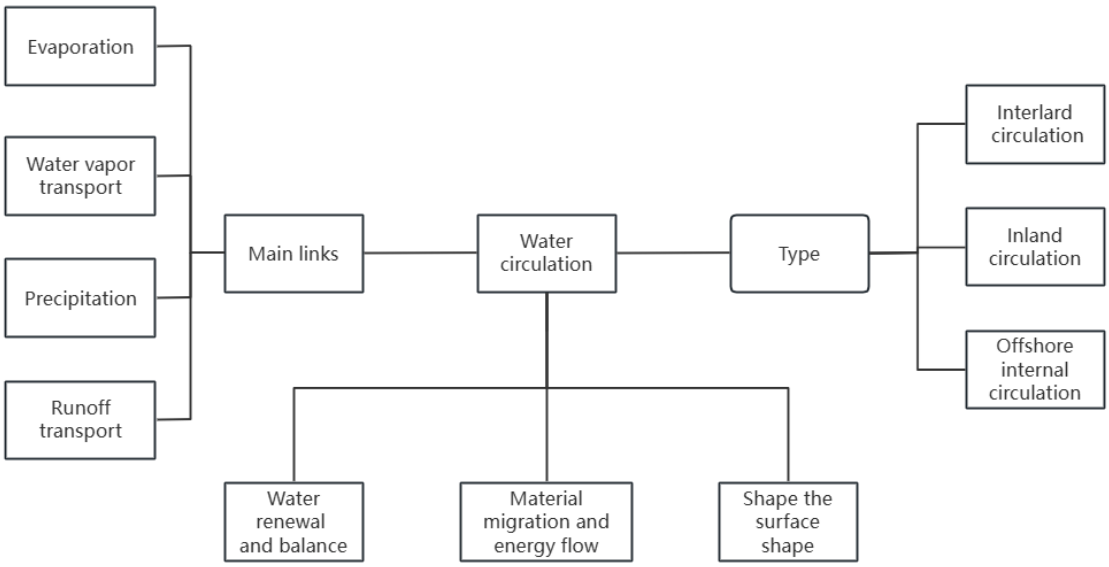

Figure 4: Conceptual structure of the water cycle

Design description: With the help of conceptual structure diagrams, the teacher displays the information in the students' brains in an intuitive and outward-looking way. Abstract thinking is thus transformed into visual images, and the structure and inner connections between knowledge are clearly shown. This visualization method can help students memorize concepts easily and promote deep understanding of concepts. Ausubel said that "students construct conceptual structure map, in fact, is to carry out a cognitive operation, this cognitive operation requires students to take the initiative to think, in-depth analysis and synthesis and generalization." In this process, students are no longer passively receiving knowledge, but actively constructing knowledge, which is a kind of deep learning.

Activity 2. Teachers present into the heavy rainfall season in a city flooding news and related materials, students are asked to analyze the process of human construction of the city on the water cycle which links caused the impact of urban flooding.

Activity 3. The teacher presents an important way to solve urban flooding - building sponge cities, and asks students to analyze the mechanism of sponge cities from the perspective of the water cycle.

Design Note: By linking geographical concepts with geographical phenomena in daily life, the teacher highlights the practicality of life that the subject of geography itself possesses. By analyzing

this case, students' overall construction of the concept of water cycle can be effectively tested. In addition, the case itself clearly reflects the importance of harmonious coexistence between human beings and nature, which will have a subtle influence on students' view of human-earth harmony.

Activity 4. Hold a debate. Forward point of view: "Although water is recycled, we still need to save water." The opposing point of view: "Because water is recycled and can purify itself, we don't need to save water." Through the debate, students realize that although water is cyclic and is constantly purifying, the rate of purification is limited, and we should pay attention to saving water in our daily life.

Design Note: Through the debate, students can not only be guided to think deeply about the water cycle, set up a correct concept of water use, and cultivate the concept of human-earth coordination, but also exercise their dialectical thinking and language skills in the process of the debate, so as to further promote the in-depth learning of geographic concepts and the development of the educational value of the discipline of geography.

6. Conclusion

APOS theory is modeled on the general cognitive process of human beings and emphasizes students' process learning, which coincides with the core concept of the new curriculum reform, "student development-oriented". Introducing APOS theory into geography concept teaching can promote the cultivation of geography core literacy while realizing the deep learning of geography concepts.

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