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Research on the Application of Advance Organizers in High-School Mathematics Teaching—Take Extrema of Functions

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Abstract

Advance organizers are effective means that can facilitate students' meaningful learning and this concept has received much attention since put forward. Advance organizers link the material students are trying to learn with what they already know, so that they can better understand the former while well remembering the latter. This research discusses how advance organizers can work in the introduction, content, and framework of teaching the extrema of functions to high-school students, thereby enabling them to study mathematics meaningfully, figure out the logic of mathematical knowledge, and build a new knowledge structure independently. We aim to provide a useful reference and path of implementation for high-school teachers to adopt the advance organizer strategy.

Keywords: advance organizer, extrema of functions, high-school mathematics teaching

1. Background

Advance organizers should be clear, stable, and abstract since they are introductory materials closely related to the course content. They can effectively prevent interference between different knowledge. People have paid much attention to studies on theories and application of advance organizers since the concept has been put forward. For example, in his article, Shi Zhiqun uses specific examples to explain how high-school mathematics teachers can adopt advance organizers from five aspects: mathematical research norms, basic ideas of mathematics, conceptual system, orientation of teaching content, and original knowledge structure (Shi Zhiqun, 2016); Li Jichao believes that an "advance organizer" can be a story, a game, an operation experiment, a set of graphs, etc. (Li Jichao, 2009). Long-term and widespread research on advance organizers has extended their connotation and denotation, alongside their application scope, and teachers have been proactively applying such a teaching strategy in daily teaching activities.

Advance organizers can play an active role in class whether students are experiencing simple connection learning or complex cognitive reconstruction. First, advance organizers allow students to study mathematics meaningfully (Luo Yongliang, 2007). Mathematics is a highly abstract and general subject, so it becomes more difficult for students to have a systematic knowledge structure in their minds as the knowledge they are learning turns increasingly abstract. Advance organizers can facilitate students' meaningful learning by helping them make non-artificial and substantive connections between old and new knowledge. Second, advance organizers render the cognitive structure clearer and more stable. With them, students can distinguish between old and new knowledge, enhance their discriminability between various knowledge, and build a clear and stable knowledge framework. Advance organizers can also improve class efficiency. Students would find it easier to understand new knowledge since advance organizers provide the preconditions for this, making teaching and learning efficient and effective.

As highlighted in the Mathematics Curriculum Standards for Compulsory Education (2022 Edition) (hereafter referred to as the "2022 Curriculum Standards"), the curriculum is increasingly concerned with students' grasp of knowledge structure and their understanding of the essential content. The advance organizer strategy places emphasis on the linkage of old and new knowledge and helps students acquire coherent and systematic knowledge, which coincides with the ideas embodied in the 2022 Curriculum Standards. Although China's nine-year compulsory education does not cover high school, we can also adapt our teaching strategies according to the 2022 Curriculum Standards in order to follow the country's educational direction.

However, under the pressure of the college entrance examination, teaching activities in practice deviate from the new teaching philosophy. First, students learn mathematics by rote and tediously. Focusing on college enrolment rate, some teachers invest more heavily in exercises, but ignore the fact that students need to understand the essence of knowledge. Second, knowledge assimilation is one-sided. Teachers tend to make students only notice the connection and difference between old and new knowledge, but do not go deeper into students' original cognitive structure (Ding Yinkai, 2017). Third, the interaction between the teacher and students is superficial and ineffective. Questions raised by teachers fail to provoke students' deep thinking, so students cannot fully comprehend what they've learned or link it with more knowledge.

These situations, resulting from teachers' understanding of reception learning, go against the prevailing educational philosophy in China, where most teachers regard reception learning in a one-sided manner and students passively accept what they are teaching. The reception learning theory proposed by David Paul Ausubel, the well-known American educational psychologist, holds that meaningful learning occurs once the learners are able to make sense of and integrate new information into the existing knowledge structures. Ausubel also put forward the concept of advance organizers. This paper briefly introduces advance organizers and uses specific teaching clips to illustrate their application in high-school mathematics teaching, in order to improve teachers' teaching models, help students learn meaningfully, and develop their core literacy.

2. Connotation and Functions of Advance Organizers

Based on his teaching practices, Ausubel put forward the theory of meaningful learning. He believes that reception learning is not passive; instead, it is active and meaningful based on what the learner already knows. Ausubel also stresses the importance of reception learning rather than discovery learning and meaningful rather than rote learning. The term "advance organizer" was first coined by Ausubel in 1960, originating from the word "organizer". He defined it as "the background conceptual material that already exists in the cognitive structure and has general significance" (David Paul Ausubel, 1994). Ausubel's theory of advance organizers falls into two categories: comparative and expository. Comparative organizers are used as reminders to integrate new ideas with basically similar concepts in cognitive structure, and expository organizers are often used when learners confuse the new learning material with what they already know.

Advance organizers, as required by meaningful learning, are introductory materials designed by the teacher based on the teaching content as well as students' cognitive level and knowledge basis, so as to help them build new cognitive structures and better grasp what they have just learned (Tian Hongjuan, 2015). In mathematics teaching, it is presented in various forms and changes flexibly. An advance organizer can be a story, a manipulative activity, a diagram, a set of problems, etc.

From the student's point of view, this introductory material can serve as a guide and orientation to the new learning materials, make students' existing cognitive structure more stable and distinguishable, and build a bridge and link between new information and existing knowledge.

From the teacher's perspective, advance organizers make each lesson much more effective while promoting students' cognitive structure to evolve continuously. Inspired by advance organizers, students will become more active and think more deeply in class, so that teachers can flexibly control the direction of class (Wang Hong, 2014). In a word, the advance organizer strategy plays an important role in making classes more productive and changing students' cognitive structure.

3. Application of Advance Organizers in Teaching

3.1 Interesting and Vivid Introduction Stimulates Students' Meaningful Learning

It is often said that "interest is the best teacher". Students' learning outcomes are not only influenced by external learning materials, but also by their motivation. If they are not interested in the content of the class, meaningful learning will never occur, no matter how well the teacher instructs students, how fully the class is prepared, and how logical the learning materials are (Jiang Hefeng, Liu Zhen & Wang Chuanlong, 2018). Therefore, during class introduction, the teacher should use content that is closely related to the knowledge taught and interesting as a prior organizer to attract students' attention, thereby ensuring an effective class.

For example, when teachers are giving a class on the extrema of functions, they can read a poem about Mount

Lu that was written by the great poet Su Shi and is familiar to students:

A range across, sideways a peak;
Far, near, high, low, no shapes alike.
You can't see Mt. Lu's true nature,
Because you're right in the picture.

Along with pictures of Mount Lu, students can observe its features. This allows students to learn the concept of extrema of functions with a preliminary intuition. Then the teacher can illustrate the first two sentences "A range across, sideways a peak; Far, near, high, low, no shapes alike", which means that Mount Lu has many "peaks" and "valleys", thus leading to the topic of the lesson. The picture of Mount Lu can be used to draw a partial graph of functions, which can improve the students' mathematical abstraction ability, and lays a foundation for a smooth and successful lesson.

3.2 Closely Linked Teaching Content Helps Students Analyze the Logic Behind Knowledge

Mathematics features concrete content, abstract form, and rigorous theories. By studying this discipline, students can master the necessary basic knowledge and skills, develop abstract thinking and reasoning ability, and cultivate a sense of innovation and practical ability. Therefore, the teacher has to help students figure out the logic between the knowledge and build a complete mathematical framework that makes for meaningful learning. The logic between knowledge refers to the natural and substantive links between knowledge and the relevant ideas that we are able to learn. Only by working out such a logic can students properly grasp the essence of mathematical knowledge, rather than having a shallow comprehension of it. In this way, in their daily exercises, they can successfully solve problems that involve what they have newly learned and also solve more problems by analogy.

During the lesson on the extrema of functions, before being asked to use the derivative to describe the extrema of a function, which is the highlight of the lesson, with an abstracted graph of the function, students can get a rough idea of the changes in the curve on either side of the maximum and minimal values, and gain the initiative to generalize the concept of extrema on their own. During this process, students would discover that both maximum and minimal values are determined in comparison with values near them and are therefore a local concept. Next, using the maximum value as an example, the teacher can ask students to analyze and describe the trend on both sides of the maximum value. Then students can derive the trend of the function on both sides of it by analogy. Again, the teacher can ask students "What can be used to describe the rise and fall of the graph of a function?", turning the description of the change in the graph into a description of monotonicity. This can be followed by another question "What can be used to describe the monotonicity of a function?", which turns the description of monotonicity into the focus of the lesson: using derivative to describe the extrema of a function.

The lesson progresses step by step—from an abstract model to model splitting based on what has been learned before, and to the key points of the lesson. Students will be more receptive to the new knowledge since it is logically and closely linked with what is already known. This approach also allows students to be deeply engaged in class, with full attention to student subjectivity.

3.3 A Clearly-Built Teaching Framework Avails Students' Construction of New Knowledge

Advance organizers guide students' thinking and motivate them to learn in a meaningful way. However, this meaningful reception learning has limitations in developing students' creative thinking. Therefore, we need to use a variety of teaching methods to combine reception learning with discovery learning in order to promote students' holistic development. When students are learning new knowledge, we can provide them with an appropriate framework based on their existing knowledge base and cognitive level, creating opportunities for independent discovery learning and facilitating the self-construction of new knowledge.

To inspire students to perform independent discovery learning in the lesson on extrema of functions, the teacher can assist students in doing so using tables, which allows them to clearly know about themselves and build a knowledge structure.

First, in terms of the point of maximum value, which we assume to be point α, students need to complete the table as shown in Figure 1. Then, as for the point of the minimal value, which we assume to be point f, students can complete the table in Figure 2 by analogy.

	Left near point a	$x = a$	Right near point a
Variation trend of the graph			

Figure 1.

	Left near point f	$x = f$	Right near point f
Variation trend of the graph			

Figure 2.

Next, we extend the above two tables to obtain another two tables in Figures 3 and 4, transforming the original problem from the trend of the graph into the monotonicity of the function.

	Left near point a	$x = a$	Right near point a
Variation trend of the graph	Up		Down
Monotonicity of the function			

Figure 3.

	Left near point f	$x = f$	Right near point f
Variation trend of the graph	Down		Up
Monotonicity of the function			

Figure 4.

Finally, we extend the tables in Figures 3 and 4 and get another two in Figures 5 and 6, which means we are now dealing with the derivative of functions, instead of their monotonicity.

	Left near point f	$x = f$	Right near point f
Variation trend of the graph	Down		Up
Monotonicity of the function	Decreasing monotonically		Increasing monotonically
$f'(x)$			

Figure 5.

	Left near point f	$x = f$	Right near point f
Variation trend of the graph	Down		Up
Monotonicity of the function	Decreasing monotonically		Increasing monotonically
$f'(x)$			

Figure 6.

In such a case, tables are serving as advance organizers and allow students to perceive the exploration of function graph more intuitively. This associates previous knowledge with new information with clear logic. In this way, students can think more clearly and understand the links between various knowledge, and build a complete mathematical knowledge structure. The transformation of thoughts and explorative process involved will also benefit subsequent studies.

4. Conclusion

Advance organizers, once applied in high-school mathematics teaching, can significantly enhance teaching efficiency and facilitate meaningful learning. Therefore, in actual teaching activities, teachers should painstakingly design reasonable and effective advance organizers to help students build a bridge between old and new knowledge, promote the assimilation of new knowledge, summon up their enthusiasm for proactive learning, and help them reconstruct and improve the knowledge structure. However, there are no determinate teaching methods, and each teacher is facing students who are different from each other. Also, teachers' teaching styles vary greatly, as do the process of lessons for different teaching contents. Therefore, the effect of the advance organizer in practice still needs to be optimized and improved by frontline teachers in light of their own actual situation. Teachers should also keep with the times, stick to lifelong learning, and constantly enrich their knowledge reserves so as to better serve the teaching practice.

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