Research on high school physics teaching under the leadership of big concepts -- taking “curved motion” as an example

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Abstract: In recent years, education is undergoing great innovation. The introduction of physics curriculum standards for senior high schools (2017 edition) indicates that teachers should change from knowledge teaching to literacy teaching. This paper is based on the guidance of the core quality of the big concept teaching as the leading, to “curve movement” as an example, trying to find this section of the course involved in the physics of the big concept, and design the corresponding physics classroom teaching program, through the authenticity of the problem as the main clue, clear teaching process of middle school students thinking guidance, help students deeply understand the physics knowledge at the same time grasp the goal of the big concept, Make them have the consciousness of deep learning.

Key words: Big concept; Core literacy; High school physics

In the General high School Curriculum Plan (2017 edition), it is clearly proposed that we should attach importance to the subject concept as the core, make the course content structured, take the theme as the guidance, make the course content contextualized, and promote the implementation of the subject core literacy. The goal of curriculum reform is to cultivate students’ core literacy, and the core of core literacy is its authenticity, so that students can complete the transfer of knowledge between different disciplines and between disciplines and real life. The traditional teaching mode is from the local scattered to the whole unity, is the superposition of the physical concepts based on the textbook, and then through the unit review to unify the segmented elements one after another. For example, in the teaching of the first Compulsory course of Physics, traditional learning focuses on students’ description of movement and the teaching of various forces of different nature in life. It is not until Chapter 4 “The Relationship between motion and Force” that the relationship between motion and force learned in the previous period is explained to form the basic system of dynamics. The method of big concept teaching is to implement the teaching from a higher Angle, use big concepts to guide students’ learning, and help students understand the big concept of the subject through many concrete cases, which is helpful to wake up the inner driving force of students.

Although the concept of big concept teaching has been studied and practiced in many places, the expert resources in most areas are limited, and teachers cannot effectively apply this concept to guide their own work. Therefore, the implementation of education is also prone to deviation. This paper takes “curve movement” as an example to carry out the teaching design, reflecting the specific approach of developing students’ core literacy based on big concept teaching, in order to provide teaching basis for senior physics teachers.

1. Connotation of the big concept of physics

Different from junior high school physics, senior high school physics is holistic and comprehensive in knowledge, in which the connection between physical concepts runs through the whole study of senior high school physics, and the arrangement of teaching materials shows a spiraling structure. As for the “motion” section, it is involved in the first two chapters of compulsory One, which mainly describes and explores the variable speed linear motion. It is not until the second compulsory that we begin to understand the curve motion, from one-dimensional straight line to two-dimensional plane; For the “force” plate, from the three basic properties of the force in compulsory one to the electrostatic force and ampere force in compulsory three, and then to the Lorentz force in Elective two; For the “Dynamics” section, it goes from Newton’s laws of motion in Compulsory 1, to the law of conservation of mechanical energy in Compulsory 2, and the momentum theorem in Elective 1. For each of these sections, each link is established with the previous knowledge and lays the groundwork for the subsequent physics knowledge. Therefore, although there are some partitions, they cannot escape from the big methodology of our study of life phenomena, that is, the big concept we say.

Curve motion belongs to the physics and kinematics of high school, the core concept of which is not to let students understand what is curve motion, nor to grasp the speed direction and conditions of curve motion. The above three are scientific conclusions obtained through observation, conjecture, experiment and reasoning. Scientific conclusions are only extended knowledge, which is a small concept. It can not realize the transfer of high path of learning. In order for students to be able to learn deeply, the most important thing is for students to understand the process of our inquiry and think about the following questions. (1) Curvilinear motion As a kind of motion on a two-dimensional plane, from what Angle should we study curvilinear motion? (2) What inspiration does the study of linear motion have for the study of curvilinear motion? (3) What kinds of feasible methods are available or have been encountered in the past to verify our conjectures? (4) How to design the scientific inquiry scheme according to the conjecture and existing equipment? From this, it can be seen that the teaching of big concepts is not stiff and pure conclusion rote memorization, but full of creativity and criticism. Students’ thinking of big concepts is more conducive to them to bring the thinking mode of physics to other subjects, and even transform it into the thinking mode of life.

2. Specific teaching process

2.1 Analysis of teaching Materials

The whole textbook closely focuses on the direction and conditions of curved movement of objects, organically combines life experience, experimental exploration, analysis and reasoning with phenomenon explanation, and progresses layer by layer, which is conducive to the cultivation of students' core literacy. From the structure of the textbook arrangement, the curvilinear movement is arranged in the first place, laying a theoretical foundation for the subsequent projectile movement. At the same time, the curvilinear movement is also the basis for the "projectile movement" that students will learn in the second year of high school, including the deflection movement of charged particles in the electric field, magnetic field and compound field. Curvilinear motion plays a very important role in the whole mechanics section of high school.

General high school physics curriculum standards the content requirements of this lesson are: through the experiment, understand the curve motion, know the conditions of the object to do curve motion. The academic requirements are: to be able to classify common mechanical motions. Ability to analyze curvilinear motion problems with knowledge of motion and interaction.

2.2 Learning situation analysis

In terms of knowledge, students have systematically studied the relatively complex variable speed motion and Newton's laws of motion in linear motion, gained a certain understanding of the relationship between force and motion, and had contact with the physical idea of limit when learning the instantaneous speed of a straight line, which gives students a certain ideological foundation when learning the direction of motion of curved motion.

2.3 Teaching objectives

According to the training requirements of students' core qualities in the new curriculum standard, the teaching objectives of the curve movement are determined from four aspects: physical concept, scientific thinking, scientific inquiry and scientific attitude and values.

(1) Physical concept: understand the concept and characteristics of curvilinear movement, and can be used to solve practical problems in life.

(2) Scientific thinking: can use limit thinking to understand the direction of instantaneous speed of curve movement; Be able to reason and demonstrate based on factual experience, and learn abstract thinking methods from the general to the special. (3) Scientific inquiry: can observe and analyze physical phenomena, put forward reasonable conjectures and hypotheses, and formulate corresponding experimental plans to explore the speed direction and movement conditions of curve movement. (4) Scientific attitude and responsibility: able to apply the knowledge of curve movement to production and life;

2.4 Important and difficult points in teaching

Teaching emphasis: to master the relationship between velocity direction and dynamics in curve motion.

Difficulty in teaching: Be able to analyze specific problems according to the characteristics of curve motion.

2.5 Teaching process design

2.5.1 Introduction of life situations to stimulate students' interest

Situation question: When the students go to school by bicycle, will the clothes on the back be wet by the muddy water brought up by the tire after passing the muddy road? What are the reasons for this phenomenon? How does mud get on our clothes by running down our tires? What is the movement of the muddy water sticking to the wheels? Student activity: Students identify with the experience and take the initiative to think about the cause of the problem. Design intention: to arouse students' learning enthusiasm and stimulate their learning drive with situations close to life.

Concept understanding: What is the track of mud and water sticking to the wheel and rotating around the wheel axis? Straight line or curve? And through the presentation of ppt, let the students understand that curve movement exists in our daily life, and abstract the definition of curve movement from the observation: the trajectory of the curve movement. Student activities: Students give examples of curved movement according to their own life experience, such as falling leaves or swinging on swings. Design intention: In this part, curvilinear movement is understood through the comparison of linear movement; Through the summary and analysis of experience, it abstracts the implementation conclusion and reflects the thinking method of induction and classification.

2.5.2 Explore the speed direction of curve movement

Situation problem: What is the velocity direction of the muddy water when it is thrown from the wheel? Provide materials: Show pictures of sparks flying out of the wheel while grinding the part, and raindrops falling off a rotating umbrella. Student activity: Summarize and guess the velocity direction of an object moving in a curve along the tangent direction of the curve. Therefore, it is judged that the moment when the mud is thrown by the wheel is also along the direction of the tangent line of the wheel. Teacher guidance: By observing these phenomena, we feel that the speed direction of curve movement may be along the tangent direction of the curve, but these phenomena are fleeting, not easy for us to study, and the examples are circular motion, circular motion is only one of the curve movement, through the special case to generalize a general conclusion, this is not a scientific way of thinking. Therefore, whether this conjecture is correct in the end, we still need to practice the test and theoretical proof

Experimental research: Display experimental equipment, 24 inch LCD small blackboard, detachable curved track, small iron ball, inclined track. And demonstrate the experimental principle and operation: on the 24 inch LCD blackboard, the teacher uses the detachable track to splice a general curved track (as shown in Figure 1), the ball falls into the track from the inclined plane, and leaves a trace on the LCD blackboard, and asks: Observe the trace on the screen, what movement does the ball do after sliding out of the track? So where is the velocity direction of the ball? The teacher guides the students to draw a conclusion, and keeps disassembling the track and repeating the experiment to verify the velocity direction of the curve motion. Student activity: Observe the trace left by the small ball on the screen, summarize and draw a conclusion. Design principle: Compared with the traditional experiment of ink, printing mud and water writing cloth, the experiment using the LCD screen to leave traces of small balls is easier to control, clean and hygienic, and the presented images are clearer and easier to be observed by students. The combination of information technology and teaching is innovative and easier to arouse students' interest.

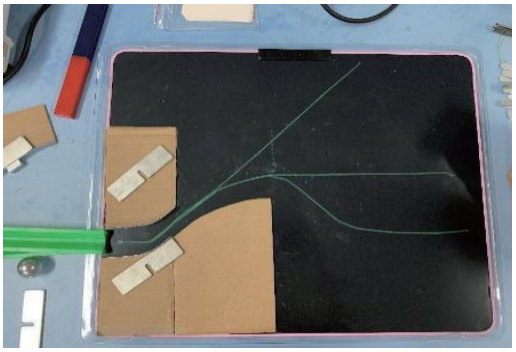

Figure 1. Experiment to explore the speed direction of curve movement

Theoretical reasoning: The teacher asked the students to recall the derivation of the instantaneous v velocity in linear motion, made a mathematical analysis of the curved motion (accompanied by the presentation pictures in ppt, as shown in Figure 2), and asked whether the direction of the instantaneous velocity in curved motion could be represented by the average velocity. In what direction does the direction of its motion follow? (secant direction of two points) how to reduce the error of instantaneous velocity? What is the relationship between the average velocity and the instantaneous velocity when two points are infinitely close to each other in a curved motion? (The average velocity at two points can be used to represent the instantaneous velocity at that point.) What becomes of the secant line connecting the two points? Student activities: The characteristics of the movement direction of the curve were finally obtained through the guidance of the teacher's question chain.

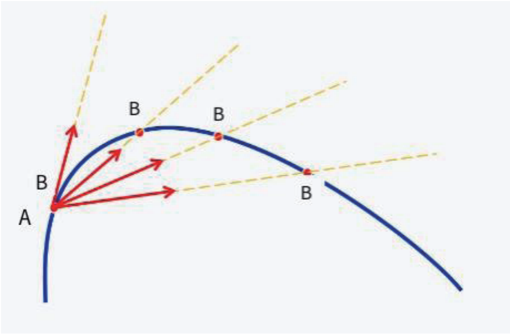

FIG. 2. Theoretical derivation of instantaneous velocity direction of curve motion

The design of bicycle mudguard: The teacher asked, according to the above conjecture, experiment and reasoning, we already know the characteristics of the curve motion speed, and please discuss the following questions: Where is the muddy water thrown from the wheel likely to splash us? How do we design a reasonable fender for the bicycle to protect our back and trouser legs from damage? Student activities: Students work in groups to discuss and draw their own fender designs on the guide plan distributed before class (see Figure 3). Design intention: The combination of real situation and teaching is conducive to the transfer of students' knowledge and the cultivation of their literacy. By leading students to guess to experiment and theory verification, the process of scientific inquiry can improve students' ability of scientific reasoning and scientific demonstration.

Figure 3. Fender design of bicycle

2.5.3 Explore the curve motion conditions

Situation question: Does the mud and water move in curve after being thrown out by the wheel? B: Why? Student activity: After discussion, it is found that the mud thrown at different positions of the wheel may move in a straight line or a curved line. Teacher question: The force analysis of the thrown mud water is carried out. What is the force acting on it? (Ignoring the air resistance) Student: Reasoning finds that the combined force is not the necessary condition for physics to do curved motion. Teacher: Please observe the picture of muddy water flying out and guess what other physical quantities are related to the curved motion? What is the relationship between the external force and the velocity direction?

Experimental investigation: The teacher guided the students to use the small steel ball, inclined plane and magnet on the table to simulate the movement of mud and water in groups, and record the experimental phenomenon, and try to reach the experimental conclusion. And let the students show their own experimental scheme, and on the stage to carry out experimental operation (as shown in Figure 4) Teacher activities: Through the observation and analysis of the experimental phenomenon, we found that when the direction of the resultant force and the direction of the velocity of the ball are not in a straight line, what does the object do? When the direction of resultant force and velocity direction of the ball are in a straight line, what does the object do? Student activities: The conditions for the object to do curved motion are finally summarized through experimental exploration. Design intention: Through observation and thinking, students can find that the movement forms of mud and water in different positions of the tire are not the same, so they have doubts about the teacher's point of view, and then carry out experimental exploration to draw a correct conclusion. It will help students develop questioning and innovative scientific thinking.

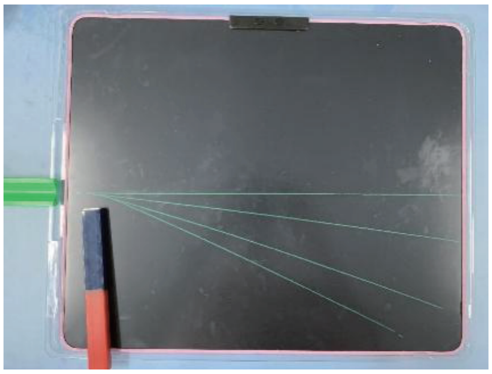

Figure 4. Explore the conditions of curvilinear movement

3 Concluding remarks

In this study, the teaching design is guided by a certain core concept. By extracting the big concept of physics, creating a big situation around the big concept, and designing the teaching process according to the big situation, the students' habit of positive thinking is effectively cultivated. Under the guidance of this habit, students can not only apply the knowledge of physics to school exams, but also help students build a bridge between the subject knowledge and the real world, lay a foundation for the transfer of their knowledge fields and deep learning, cultivate students' practical problem-solving ability, and have certain practical value for the cultivation of students' physics literacy.

Reference literature:

[1] Ministry of Education of the People's Republic of China. Senior High School Curriculum Plan (2017 edition) [S]. Beijing: People's Education Press,2017.

[2] Xuyuan Chen. Curriculum and Teaching Theory [M]. Beijing: Higher Education Press,2012.

[3] Ministry of Education of the People's Republic of China. Physics Curriculum Standard for Senior High School (2017 edition to be revised in 2020) [S]. Beijing: People's Education Press,2020.

[4] Gang Chen,Xinjie Hou. Middle School Physics Curriculum and Teaching [M]. Shanghai: East China Normal University Press,2018.

[5] Jianpeng Wu. Construction and Design of large unit physics teaching in high school from the perspective of Big Concept -- A case study of Newton's Laws of Motion teaching [J]. Reference for Middle School Physics Teaching, 201,50(11):25-27.

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