Education Reform and Development, 2025, Volume 7, Issue 2
https://ojs.bbwpublisher.com/index.php/ERD
Online ISSN: 2652-5372
Print ISSN: 2652-5364

Particle Model Teaching Promotes the Development of High School Students' Modeling Ability

Wenjing Fu , Zhenfa Zi*

School of Physics and Materials Engineering, Hefei Normal University, Hefei 230601, Anhui, China

***Corresponding author:** Zhenfa Zi, zfzi@issp.ac.cn

Abstract: Using the "particle" as the first physical model in high school teaching, educators should focus on real-life situations in the classroom, emphasizing the underlying problems. Through a "problem chain" approach, teachers guide students to pay attention to the process of model construction. This approach helps reinforce and expand modeling skills through situational problem training, improving students' ability to transfer knowledge. It also enhances their core physics literacy and fosters their overall development.

Keywords: Particle; Model construction; High school physics; Core literacy

Online publication: March 7, 2025

1. Introduction

With the introduction of the Physics Curriculum Standards for Senior High School (2017 Edition, 2020 Revision), the core literacy in physics has become the foundation of the curriculum. Model construction is a crucial element of this core literacy, helping students deepen their understanding of physics and improving their ability to apply concepts in different situations [1]. In response to the country's demand for talent with advanced thinking and high-level skills, the reform of middle school physics is focused on developing the core literacy of the subject. The model constructs the key abilities that high school students must possess and need to develop continuously.

Since 1980, David Hestenes, an American theoretical physicist, first proposed the model-centered teaching method. Since then, physics modeling teaching has gradually attracted the attention of many foreign scholars, such as Halloun, Clement and Jim Schmitt, who all proposed relevant modeling teaching theories on this basis. In 2013, "Model building" was listed as one of the eight important practical activities in the "Standards for New Generation Science Education" (NGSS). In addition, France, Australia and other countries have also emphasized the important role of model in their curriculum documents [2, 3]. Since the release of the "new curriculum standard" in China, the number of literature on physics modeling teaching has shown an explosive growth and most of them are theoretical research and exercise research [4, 5]. Although domestic scholars and front-line teachers have given a certain degree of attention to the construction of physical modeling. However, there are still many shortcomings in the actual teaching process. Nearly one-third of the students still lack the ability to build physical models and have difficulty extracting models from real situations. Students still stay in the conventional problem-solving methods, lack the ability of transfer and application, which is not conducive to the cultivation of core literacy.

Professor Liao believes that "Model construction is the starting point for cognition of physical phenomena and scientific thinking. It abstracts and simplifies the phenomena based on the needs of research and forms a new image that is easy to study and can reflect the essential characteristics of things by ignoring the secondary factors and highlighting the main ones. The new image can be an ideal model, ideal process, ideal experiment and physical concept" [6]. Among them, "particle" is the topic covered in the first section of Chapter 1 in the compulsory high school physics curriculum of the Human Education edition. It is the first physical model in the learning stage of high school and the first time to think about problems with relatively standardized modeling thinking [7]. For students who have just entered high school, the difficulty of physics learning increases significantly. The key to successfully bridging this initial gap lies in shifting their mode of thinking. Training students' physical modeling ability can help students realize this leap and better adapt to high school learning. Therefore, it is very important for high school students to preliminarily understand and master the construction of "particle point" model.

Table 1. Requirements of the 2003 and 2017 curriculum standards for "particle"

2003 Edition	2017 Edition
Through the understanding of particles, understand the characteristics of physical models in physics research and experience the role of physical models in exploring the laws of nature [8].	Experience the construction process of particle model and understand the meaning of particle. Know the conditions for abstracting objects into particles, and can abstract objects into particles in specific practical situations. Experience the way of thinking of building physical models and understand the role of physical models in exploring the laws of nature [9].

As shown in Table 1, the knowledge requirements for the concept of the particle in the two versions of the curriculum standards are basically the same. However, in the new curriculum standards of 2017, behavioral verbs such as "experience... the construction process", "know... conditions", "be able to... abstract into", "appreciate... the way of thinking", and "understand... role" have been added, which places greater emphasis on students' ability to independently construct physical models. The 2017 edition of the "New Curriculum Standard" divides model building ability into five levels, from level 1 (able to tell some simple physical models) to level 5 (able to convert objects and processes in more complex practical problems into physical models) [10]. Students have experienced the process from passive memorizing physical models to active self-constructing physical models. In order to make students reach the modeling ability required by the "new curriculum standard", teachers need to adopt appropriate teaching strategies in the teaching process to promote the development of high school students' modeling ability.

2. The teaching of particle model construction

2.1. Focus on the situation and highlight the original problem

Primitive physical problems are typical physical phenomena and facts that exist objectively in nature, social life, and production, unprocessed and raw. These problems directly reflect the most authentic physical situations in real life [11]. In the teaching process of "primary points", teachers should fully analyze the learning situation, pay attention to and think about the life situation from the perspective of students, find the original problems, and trigger the students' concern and cognitive conflict. Learning physics goes beyond simply memorizing textbook knowledge; it also requires students to think critically and reflect. By connecting physics knowledge with real-life situations and applying it, students can better understand the methods of physical modeling. This approach helps stimulate their enthusiasm and initiative for learning physics. Only by constructing a scientific physical model through the path of solving the original problem can high school students better develop their physical modeling ability and improve their core literacy of physics.

Table 2. Case fragment of "problem situation" in teaching of "particle" model

Teaching elements	Teacher activities	Student activities	Design intent
Situation introduction	Multimedia presentation: motion video of the high-speed train Q: Can you accurately describe the movement of the high-speed train in the video?	Student description: When the high-speed train turns a corner, the body of the train inclines to a certain extent, and then it passes through the cave in a straight line...	Cultivate students' ability of observation and lay the foundation for the construction of the model
Difficulties in actual motion description	Teacher question: It is not easy to describe the motion of an object accurately. What are the main problems and difficulties? How can we solve it?	The students got into thinking mode	Highlight the original problem, causing students' concern and cognitive conflict.

Based on the example in **Table 2**, the teacher brings attention to the core problem using a real-life situation and explores the sources of the students' thinking difficulties. The teacher also addresses how these challenges can be overcome. Some students may feel that the problem would be easier if it were simpler. Through the teacher's guidance, students engage in the thought process of simplifying the research topic and developing the "particle" model. This experience helps enhance their modeling skills and sets the foundation for the next phase in constructing the "particle" model.

2.2. Guide in the form of a chain of problems, focusing on the physical model-building process

Thinking is often implicit, and so is the model construction, which is also part of scientific thinking. Students may believe memorizing the physical models and conditions they've learned is sufficient. However, this perspective is shallow, as it overlooks the importance of understanding the reasoning and processes behind model construction. As a result, when students face real-world problems, they struggle to transfer and apply their thinking, since they have not developed a clear and flexible physical model [12]. In traditional teaching, if the teacher does not design a well-structured question chain, even though real-life situations are introduced, the questions may be scattered and lack logical coherence. As a result, students often fail to develop clear, logical thinking and may end up waiting for the teacher's answer.

In this scenario, knowledge is "forced" upon students by the teacher rather than being internalized and understood by the students themselves. This approach does not effectively cultivate students' ability to think independently or build models. To better present the thinking process of constructing the "particle" model, teachers should design corresponding classroom activities and problems in advance and transform the recessive modeling process into explicit. In student-teacher and student-student interactions, students are able to express their underlying thought processes through language. This not only boosts their participation in class but also allows teachers to identify any issues students may have and provide prompt corrections. In this way, it is more helpful to understand students' grasp of knowledge and develop students' ability to construct physical models [13].

The construction of the "particle" model shown in **Table 3** is not to list one situation after another for students to discover and summarize, but to carry out the specific activity of "calculating the time spent on high-speed railway in different situations". The teaching method of "problem chain" gradually guides students to initially construct the "particle" model. Students came up with the concept of "point" by themselves and experienced the thinking process of model construction in person, to express their own views on whether the shape and size of objects are ignored in different situations in life. The teaching based on the "problem chain" allows students to deeply understand the thinking mode of idealized models and lays the groundwork for the learning of other physical models in high school.

Table 3. Case segment of "problem chain" in "particle" model teaching

Teaching elements	Teacher activities (proposing a "chain of questions")	Student activities	Design intent
Construction of the particle model	Q1: Given the speed, what factors should be taken into account when the high-speed rail passes through a tree?	Student group discussion: At this time, the motion state of the train can be ignored, only the length of the high-speed train needs to be known. The students drew the high-speed train and the tree to a certain scale.	Through three related questions, students were asked to think about the factors to be considered in the construction of the model
	Q2: Given the speed, what factors should be taken into account when the high-speed railway crosses the Yangtze River Bridge?	Student group discussion: They need to know the length of the Yangtze River Bridge and the high-speed rail. The students drew the Yangtze River Bridge and the high-speed train to a certain scale.	
	Q3: Given the speed, what factors should be taken into account when it takes a high-speed train from Shanghai to Beijing?	Student discussion: If the train is longer than the distance from Shanghai to Beijing, you can know the distance from Shanghai to Beijing without considering the shape and size of the high-speed train. The students drew the bullet train as a dot to scale.	
	Q4: What was your experience when you drew it?	The proportion of high-speed iron on the paper is getting smaller and smaller and when the shape and size have no effect on the displacement, the object can be reduced to a point without shape and volume.	It embodies the students' subjectivity
	Q5: What factors have been overlooked in this process? Why?	Student discussion: Ignoring shape and size. Because seeing the object as a point does not affect the study of the problem.	Instruct students to summarize the meaning of the particle model for themselves
	Q6: What elements have been retained in this process? Why?	Student discussion: Quality.	
	T: Establish the concept of mass		

2.3. Situational problem training to consolidate physical modeling ability

In traditional teaching, many teachers think that the content of "particle" is too simple, and they directly explain the next knowledge point after constructing the "particle" model, without introducing new situations to guide students to construct independently. This kind of teaching method is not conducive to the development of students' modeling ability and transfer ability. Exercise training can make students understand the nature of the modeling process, grasp the main contradiction, ignore the secondary contradiction, and clear the applicable conditions of the model [14]. When selecting and designing exercises, teachers should refer to the evaluation system of the "new college entrance examination", which outlines the structure and focus areas of the examination. Compared with traditional non-contextualized questions, contextualized questions only take one step more. Extracting key information from situational questions to construct physical models requires higher scientific thinking ability of students, which requires students to have higher physical modeling ability and higher cognitive ability to flexibly apply knowledge to analyze and solve practical problems.

Example: About particles, the following statement is correct ()

A. When studying the motion of the eight planets around the sun, the planets are too large to be considered as particles

B. When studying the geographical location of a large truck traveling on the road, the large truck can be regarded as a particle.

C. When studying the motion state of a train turning on a curve, the train can be regarded as a particle.

D. When studying the dance movements of a dancer on the stage, since the dancer needs to run around on the stage, the dancer cannot be regarded as a particle.

The four choices in this question are all contextualized and closely related to production and life. In the process of solving the problem, students need to independently discover the original problem in the situation, highlight the main factors, ignore the secondary factors, and experience the process of building a physical model. Particle is both a physical abstraction and an idealized model. Specifically, when the shape and size of an object can be disregarded in relation to the problem being studied, the object can be considered a particle. For example, when the truck is driving on the highway and the geographical location of the truck is studied, the truck can be regarded as a particle. But when we study the motion of the eight planets around the sun, the motion of a train in a curve, or the movements of a dancer on a stage, the eight planets, the train, and the dancer cannot be regarded as particles.

To further consolidate the ability of physical modeling, teachers should encourage students to copy the "particle" model by themselves after class and form a model card as shown in **Table 4.**

Table 4. Construction of the "particle" model

New teaching introduces context	High-speed trains, Eagles
Major factors	Quality
Secondary factors	Size and shape
Model construction	Quality: having mass; point: having no size or shape
Related knowledge	Know that "idealization" is a widely used research method in scientific research
Other important properties	The effect of an object on a research problem is independent of the size of the object itself

3. Conclusion

As one of the elements of scientific thinking, model construction is also an important part of the core literacy of physics, which is of great significance to the all-round development of students. The teaching mode based on model construction is based on students' learning-oriented ability teaching. Physical model construction can concretize students' thinking process. In the process of model construction, students sort out and integrate physical concepts, form laws and apply them into practice. Pay attention to the life situation, highlight the original problem, guide in the form of "problem chain" and train and consolidate through the problem situation, to promote the development of high school students' physical modeling ability.

Disclosure statement

The authors declares no conflict of interest.

References

[1] Ministry of Education of the People's Republic of China, 2020, Curriculum Standards for General High School Physics. People's Education Press, Beijing.

[2] Liu J, 2024, Practical Research on Cultivating Physical Model Construction Ability under the Combination of Virtual-Reality Teaching Situation, thesis, Qinghai Normal University.

[3] Wang D, 2023, Research on High School Physics Model Teaching Based on Deep Learning Concept, thesis, Soochow University.

[4] Wang Y, Jiang W, 2023, Review and Reflection on the Research of Physics Discipline Model Construction. Middle School Physics, 41(13): 8–13.

[5] Niu P, 2022, Training of High School Students' Physical Model Building Ability, thesis, Shandong Normal University.

[6] Liao B, 2020, Interpretation of Physics Curriculum Standards for Senior High School. Higher Education Press, Beijing.

[7] Xia Y, Nie Y, Zhou X, 2019, Innovative Teaching Design of "Life" to Make the Particle "Alive". Physics Bulletin, 2019(08): 80–83.

[8] Ministry of Education of the People's Republic of China, 2003, Physics Curriculum Standard for Senior High School. People's Education Press, Beijing.

[9] Zhang J, 2023, Strategy Research on Cultivating High School Students' Core Physics Literacy Based on Situational Teaching, thesis, Southwest University, 2023.

[10] Zhang Z, 2019, Teaching Strategies of Physical Model Construction in Senior One, thesis, Qufu Normal University.

[11] Xing H, Chen Q, 2006, Thinking on Teaching Primitive Physics Problems. China Education Tribune, 2006(08): 67–69.

[12] Infante DA, Rancer AS, 1982, A Conceptualization and Measure of Argumentiveness. Journal of Personality Assessment, 46(1): 72–80.

[13] Chen H, 2019, Physics Teachers, 45(04): 8–12.

[14] Zeng Q, 2023, Deep Exploration of Exercise Content to Improve Modeling Ability. Reference for Middle School Physics Teaching, 52(28): 1–4.