2024 Volume 2, Issue 2
Contemporary Education Frontiers
ISSN (Online): 3029-1860 ISSN(Print): 3029-1879

Exploring the Cognitive Obstacles in High School Students' Learning of Physics and Mechanics

Xing Lyu*
Ningbo Yinzhou Senior High School, Ningbo 315100, Zhejiang Province, China

***Corresponding author:** Xing Lyu, 3472324729@qq.com

Abstract:

Physical mechanics, as an important part of high school physics, requires high demands on students' logical thinking and analytical abilities. However, in practical learning, high school students often encounter many difficulties in the mechanics section. There are various thinking barriers behind this, which hinder their in-depth understanding and effective application of mechanics knowledge. This article explores the thinking barriers that high school students face in learning physics and mechanics from their perspectives. By analyzing the understanding of mechanical concepts, problem-solving processes, experimental operations, and other aspects, combined with specific examples, this study reveals the common forms of thinking obstacles and their causes in students' learning of mechanics. At the same time, corresponding strategies to overcome thinking barriers were proposed to help high school seniors better grasp knowledge of physics and mechanics, and improve learning efficiency and grades.

Keywords:

High school students
Physical mechanics
Cognitive impairment
Effective strategy

Online publication: December 16, 2024

1. Introduction

Physical mechanics is an important component of high school physics and one of the key examination contents in the college entrance examination. However, in the actual learning process, many high school seniors face many difficulties in studying physics and mechanics, with varying degrees of thinking barriers. These thinking barriers not only affect students' understanding and mastery of mechanics knowledge but also hinder their ability to improve their problem-solving skills in mechanics. Therefore, in-depth exploration of the thinking barriers of high school students in physics and mechanics learning is of great practical significance for improving the quality of physics teaching and students' learning outcomes [1].

2. The significance of high school students studying physics and mechanics

2.1. Cultivate logical thinking ability

The study of physical mechanics requires rigorous analysis and reasoning. In the process of solving mechanical problems, students need to clarify known conditions, determine the research object, analyze the force situation of the object, and use knowledge such as Newton's laws of motion to derive and calculate. This process can greatly exercise students' logical thinking ability, enabling them to learn to think systematically and identify essential laws from complex phenomena. This logical thinking ability not only plays an important role in physics learning, but also has a positive impact on the learning of other disciplines, as well as future university studies and careers [2].

2.2. Enhance problem-solving skills

Mechanical problems often have a certain degree of complexity and comprehensiveness, requiring students to apply multiple knowledge points and methods comprehensively to solve them. Through continuous practice and contemplation of mechanics problems, students can gradually master strategies and techniques for problem-solving. When facing practical problems, being able to quickly analyze the key points of the problem and choose appropriate physical models and methods for solving them is important. The improvement of problem-solving ability not only helps students achieve good grades in physics exams but also enables them to better cope with various challenges in daily life. For example, when encountering practical mechanical phenomena in daily life, such as calculating the braking distance of a car or analyzing the structural stability of a building, students can apply their knowledge of mechanics to analyze and solve them, enhancing their understanding and control of their lives.

2.3. Laying the foundation for future development

For high school seniors who aspire to apply for science and engineering majors, studying physics and mechanics lays the foundation for their future university studies and career development. In the science and engineering majors of universities, physical mechanics is an important foundation for many professional courses, such as mechanical engineering, civil engineering, aerospace engineering, and many more. A solid foundation in mechanics can make it easier for students to understand and master professional knowledge during their university studies, preparing them for future career development. Even for students who do not choose science and engineering majors, the thinking and problem-solving abilities cultivated in the process of studying physics and mechanics will play an important role in other fields, such as research in humanities and social sciences, which also require logical thinking and analytical problem-solving skills [3].

3. Thinking obstacles in understanding mechanical concepts

3.1. Inaccurate understanding of the concept of force

In the study of mechanics, force is a fundamental concept. However, some high school seniors have a biased understanding of the concept of force. Some students believe that force is the cause of object motion, rather than the cause of changing the state of object motion. This erroneous understanding can lead students to make mistakes when analyzing changes in the motion state of objects. For example, when analyzing the motion of an object moving uniformly in a straight line on a smooth horizontal plane suddenly subjected to a horizontal force, some students mistakenly believe that force is the cause of the object's motion, and therefore assume that the object will immediately accelerate after being subjected to force, ignoring the important factor of inertia.

3.2. Confusion of the concept of acceleration

Acceleration is a physical quantity that describes the speed at which an object changes, but some students tend to confuse acceleration with the magnitude and direction of velocity. Some students believe that objects with high acceleration necessarily have high velocity, or that objects with zero acceleration also have zero velocity. For example, if an object is moving at a constant speed in a straight line, some students believe that the acceleration of the object is high because of its high speed. In fact, the acceleration of an object in

uniform linear motion is zero.

3.3. Thinking barriers during the problem-solving process

3.3.1. Lack of systematic problem analysis

When solving mechanics problems, some high school seniors lack systematic analysis methods and often rely solely on intuition or experience to solve them. They did not develop a habit of starting from known conditions, gradually analyzing problems, establishing physical models, and selecting appropriate formulas for solving them. For example, when solving a mechanical synthesis problem involving multiple objects and processes, some students do not know where to start and do not conduct a systematic analysis of the problem, resulting in a chaotic problem-solving process and numerous errors.

3.3.2. Rote memorization of formulas and a lack of ability to apply them flexibly

Some students only memorize various formulas by rote when studying mechanics, without understanding the physical meaning and applicable conditions of the formulas. When solving problems, they often mechanically apply formulas without considering the actual situation of the problem.

For example, when calculating the friction force of an object on a slope, some students simply apply the sliding friction force formula, $f = \mu \times N$ regardless of the object's motion state, without considering that the magnitude of the friction force should be determined based on the object's force balance when the object is stationary on the slope.

3.4. Thinking obstacles in experimental operations

3.4.1. Insufficient understanding of the experimental purpose and principles

In physics experiments, some students do not have a deep understanding of the experimental purpose and principles, and only mechanically follow the experimental steps without knowing why they need to do so. This kind of thinking disorder can lead to students lacking initiative and creativity in the experimental process, and being unable to gain real knowledge and skills from the experiment. For example, when conducting experiments to explore the relationship between acceleration, force, and mass, some students only follow the steps in the experimental manual and do not understand why it is necessary to explore the relationship between acceleration, force, and mass by changing the mass and tension of the car.

3.4.2. Insufficient ability to process experimental data

After the experiment, processing the experimental data is also an important step. However, some high school seniors have insufficient abilities in experimental data processing. They do not know how to choose appropriate methods to process experimental data, nor can they correctly analyze experimental data to conclude. For example, after experimenting with measuring the gravitational acceleration of an object, some students do not know how to use the experimental data to calculate the gravitational acceleration or make errors during the calculation process.

4. Strategies for overcoming thinking obstacles in high school students' learning of physics and mechanics

4.1. Strengthen the learning of basic knowledge

4.1.1. Emphasize the understanding of concepts and laws

The concepts and laws in physical mechanics are the foundation of learning. Senior high school students should have a deep understanding of the connotations and extensions of basic concepts such as force, acceleration, and Newton's laws of motion. For example, in terms of the concept of force, it is necessary to clarify that force is the interaction between objects. It is not only necessary to know the three elements of force: magnitude, direction, and point of action, but also to understand the characteristics and production conditions of forces with different properties. For Newton's second law, $F = m \times a$, it is necessary to accurately grasp the relationship between acceleration, force, and mass, and understand how to apply this law for analysis and calculation in different situations.

4.1.2. Consolidate the application of mathematical knowledge

The solution to physical mechanics problems often

involves mathematical knowledge, such as trigonometric functions, vector operations, geometric shapes, and many more. Senior high school students should strengthen their review and consolidation of mathematical knowledge, and improve their ability to apply it to physics problems. For example, when solving the problem of force decomposition, it is necessary to apply knowledge of trigonometric functions. When analyzing the motion trajectory of an object, the properties of geometric shapes may be used [4]. By continuously practicing, we can closely integrate mathematical knowledge with physics and mechanics problems to improve the accuracy and efficiency of problem-solving.

4.1.3. Conduct a systematic knowledge review

As a senior high school student, one can systematically organize knowledge of physics and mechanics through creating mind maps, summarizing notes, and other methods. Organize the various knowledge points of mechanics according to a certain logical relationship to form a clear knowledge framework. This helps to quickly retrieve the required knowledge when solving problems, avoiding situations of knowledge confusion and omissions. For example, mechanics can be divided into three parts: statics, kinematics, and dynamics, and the knowledge points of each part can be summarized separately to clarify the connections and differences between each part.

4.2. Improve learning methods

4.2.1. Proactive inquiry-based learning

Change the traditional passive way of learning knowledge and actively engage in inquiry-based learning. When studying physics and mechanics, do not rush to look for answers or consult teachers when encountering problems, but first think and try to solve them on your own. By consulting materials, conducting experiments, and other methods, we can delve into the essence and solutions of the problem. For example, when studying Newton's second law, there is a problem: an object with a mass of m is placed on a smooth horizontal plane and subjected to a horizontal constant force F, and the acceleration of the object is calculated. By analyzing the force situation of the object, the resultant force is determined as F, and then according to Newton's second law, $F = m \times a$, the acceleration, $a = F/m$, can be easily obtained. In this process, the thinking mode of force analysis and formula derivation was applied. Firstly, clarify the research object, then conduct force analysis on it, and select appropriate formulas for calculation based on known conditions. This kind of thinking makes us more organized when solving mechanical problems.

4.2.2. Do more typical examples and analyze mistakes

Doing typical examples is an effective way to master knowledge and problem-solving methods in physics and mechanics. Senior high school students should choose some representative examples for in-depth analysis and practice, and summarize problem-solving ideas and techniques. Simultaneously, it is important to pay attention to error analysis, identify the reasons for one's mistakes, and promptly correct and summarize them. By analyzing incorrect questions, one can discover their shortcomings in knowledge understanding, problem-solving methods, and other aspects, and make targeted improvements and enhancements. For example, if one frequently makes mistakes in the synthesis and decomposition of forces, specialized reinforcement exercises can be conducted to summarize problem-solving methods and precautions for different situations.

4.2.3. Collaborative learning and exchange discussions

Collaborating with classmates for learning and communication can broaden one's thinking horizon and discover blind spots. In the process of studying physics and mechanics, high school seniors can form study groups to discuss problems and share their learning experiences. In discussions, different viewpoints and ideas collide with each other, which can stimulate students' thinking vitality and help them better understand and master mechanics knowledge. For example, for a complex mechanical synthesis problem, group members can analyze it from different perspectives, propose their solutions, and then discuss it together to find the optimal solution.

4.3. Breaking the fixed mindset

4.3.1. Cultivate innovative thinking

In the study of physics and mechanics, high school seniors should dare to question traditional problem-solving methods and thinking patterns and cultivate

innovative thinking. They should try to think about problems from different perspectives and find new solutions. For example, when solving the motion problem of an object on a slope, in addition to conventional force analysis methods, the law of conservation of energy can also be considered to broaden the problem-solving approach. Concurrently, we should actively participate in some technological innovation activities, such as physics competitions, and technological inventions, to exercise our innovation and practical abilities.

For example, when studying the chapter on "Balance of Objects," one encounters a problem scenario where there is a slanted wedge on rough horizontal ground and a small object is placed stationary on top of the wedge. The teacher requested an analysis of the force distribution and interaction between small blocks and oblique splits. When analyzing the force on small objects, the thinking of isolation method was applied. Take out the small object separately for analysis, considering that it is affected by gravity. Furthermore, due to the small object being stationary on the diagonal split, it is inevitably subjected to the support force of the diagonal split. Further thinking, small objects tend to slide downward relative to the inclined plane, so they will be subjected to the static frictional force along the inclined plane caused by the inclined plane. Under the holistic approach, small objects and oblique splits are viewed as a whole, which is in a state of equilibrium due to gravity, ground support, and friction provided by the ground. Through this case, it can be seen that the thinking of isolation method and holistic method are very important in the study of physical mechanics. For complex mechanical problems, by appropriately applying these two methods, it is possible to analyze the force situation of objects more clearly, thereby better understanding and solving problems [5].

4.3.2. Avoid empirical errors

Students are often influenced by past experiences during the learning process, which can easily lead to empirical errors. In the study of physics and mechanics, high school seniors should always remain vigilant and avoid relying solely on experience to judge problems. Careful analysis and reasoning should be conducted for every problem, and experience should not be blindly applied. For example, after learning about electric and magnetic fields, some students may confuse the properties of electric and magnetic forces, which is influenced by their previous mechanical knowledge and experience. To avoid empirical errors, it is necessary to compare and analyze the characteristics of different types of forces.

4.3.3. Conduct thinking training

Special thinking training methods such as reverse thinking, divergent thinking, and many more can be used to break through thinking patterns. Reverse thinking refers to thinking from the opposite direction of a problem to find a solution. For example, when calculating the force situation based on the known motion state of an object, it is possible to first assume that the object is not under force, and then gradually analyze the force situation based on the actual motion state of the object. Divergent thinking is the process of starting from a problem and coming up with as many different solutions as possible. Through these thinking exercises, students' flexibility and creativity in thinking can be improved, and they can better cope with various problems in the study of physics and mechanics.

4.4. Optimize textbook content and teaching methods

4.4.1. Optimization of textbook content

Textbook writers can optimize the content of physics and mechanics to better meet students' cognitive laws and learning needs. Add some vivid and interesting examples and experiments to improve the readability and attractiveness of the textbook. For example, when explaining Newton's laws of motion, real-life examples such as car braking and athlete starting can be introduced to help students better understand the application of the laws. At the same time, the difficulty gradient of the textbook should be appropriately reduced, so that students can gradually learn mechanics knowledge and avoid developing fear of difficulty due to excessive challenges.

4.4.2. Diversified teaching methods

Teachers should adopt diverse teaching methods in the teaching process to stimulate students' interest and enthusiasm for learning. For example, experimental teaching methods can be used to allow students to observe and experience physical phenomena through

hands-on experiments, deepening their understanding of mechanics knowledge. Multimedia teaching methods such as animations and videos can also be used to visually present abstract mechanical concepts and laws to students. Additionally, problem-driven teaching methods, and inquiry-based teaching methods, among others, can effectively improve students' thinking and problem-solving abilities. Teachers should choose appropriate teaching methods based on different teaching content and students' actual situations to improve teaching effectiveness.

4.5. Reforming the examination evaluation system

4.5.1. Emphasize the examination of thinking ability

The current examination evaluation system mainly focuses on assessing students' mastery of knowledge, with relatively less emphasis on testing their thinking abilities. To guide students to pay more attention to the cultivation of critical thinking skills, the examination and evaluation system should increase the intensity of testing thinking ability. Open-ended and exploratory questions can be set up, requiring students to apply their learned mechanics knowledge and thinking methods to analyze and solve problems. For example, providing an actual mechanical problem scenario, allowing students to propose problems, design experimental plans, conduct data analysis, and draw conclusions, comprehensively testing students' thinking and innovation abilities.

4.5.2. Diversified evaluation methods

In addition to traditional exam evaluation methods, diversified evaluation methods can also be adopted to comprehensively evaluate students' learning processes and learning outcomes. Teachers can evaluate students' learning attitudes, thinking processes, and practical abilities through classroom performance, homework completion, experimental reports, group cooperation, and other aspects. This can encourage students to actively participate in the learning process and improve learning outcomes. Simultaneously, the evaluation results should be promptly fed back to students, allowing them to understand their strengths and weaknesses and make targeted improvements and enhancements.

5. Conclusion

In summary, as high school students, there are various thinking barriers in the study of physics and mechanics. These thinking barriers not only affect students' understanding and mastery of mechanics knowledge but also hinder their ability to solve mechanics problems. By analyzing the understanding of mechanics concepts, problem-solving processes, experimental operations, and other aspects, we have revealed the common forms of thinking barriers and their causes in our study of mechanics. We hope these strategies can help us better grasp the knowledge of physics and mechanics and improve our learning efficiency and grades.

Disclosure statement

The author declares no conflict of interest.

References:

[1] Zhou J, 2024, Analysis of Strategies for Implementing Innovative Education in High School Physics Teaching. Guangxi Physics, 45(01): 109–111.

[2] Tian X, Jiang C, Zhang Q, et al., 2023, Assessment and Teaching Suggestions for High School Students' Scientific Reasoning Ability Based on Physical Scenarios. Physics Teaching, 45(12): 7–12 + 71.

[3] Chen S, 2023, Advanced Study on the Integration of Conceptual Understanding and Physical Modeling Ability in High School Students, thesis, Zhejiang Normal University.

[4] Wang H, 2020, A Study on the Thinking Obstacles of High School Students in Physics and Mechanics Learning. China New Communications, 20(18): 205.

[5] Haize R, 2020, Exploration of Problem-Solving Skills and Application Practice in High School Physics Mechanics. Science and Technology Wind, 2020(09): 35 + 37.