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Teaching the Fundamentals of Natural Science Through Scientific Model Construction[1]

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[1]Zhaoqing University 's higher education teaching reform project in 2024 (No.zlgc2024031): Research on the curriculum setting of primary education based on practice orientation, Zhaoqing University 's school-level scientific research project in 2026: Exploration on the practical path of STEAM education in rural primary and secondary schools under the background of vertical assistance of normal universities. Zhao Shudong, male, associate professor, doctor, is mainly engaged in scientific education research.

Abstract: ***This study explores the use of scientific-model construction in teaching the "Natural Science Foundation" course for primary-education majors. Using the sinking and floating unit as an example, the activity of producing an underwater glider model enables students to deepen their understanding of scientific concepts and apply them in practice. The approach helps shift instruction from theory-centered delivery to active participation, strengthens students' learning motivation, and supports the development of scientific literacy.***

Keywords: Scientific Model; Modeling; Scientific literacy; Teacher education; Natural science teaching

1. Introduction

In January 2025, the General Office of the Ministry of Education issued the " Guidelines for Science Education in Primary and Secondary Schools " emphasizing that we should follow educational principles, pay attention to teaching students in accordance with their aptitude, stimulate students ' interest in science, and comprehensively improve the quality and level of science education in primary and secondary schools. As the main position for the training of science teachers in primary and secondary schools, normal colleges and universities should actively implement the overall deployment of the state for the training of science education talents, vigorously promote the reform of college curriculum, innovate teaching methods, and strengthen the cultivation of students ' scientific literacy. In the process of carrying out the teaching of " Natural Science Foundation " course for normal students majoring in primary education, the author explores the practical teaching by using the idea of scientific model, aiming at improving students ' learning motivation and interest, so as to improve the teaching effect of this course.

2. The Main Problems Faced by the Teaching of " Natural Science Foundation " Course

"Natural Science Foundation " is a comprehensive course aimed at cultivating the scientific spirit, scientific attitude and scientific ability of contemporary college students. The content includes material science, life science, earth and universe science, technology and engineering, etc. It involves the history of natural science development, the basic attributes of nature, the relationship between resources and environment, the application of science and technology, and the complex relationship between human beings and nature.

However, due to the constraints of hours and teaching resources, the course of " Natural Science Foundation " has the current situation of " placing more weight on theory while limiting practice " in teaching practice. In the course of teaching, scientific experiments are limited to demonstrations or simple video presentations, which cannot stimulate students ' interest and enthusiasm for inquiry. The results of the survey show that normal students majoring in primary education have a certain understanding of the knowledge structure of natural science, but they are weak in the ability to use scientific knowledge and solve practical problems. This situation has a certain relationship with their limited practical engagement（Zhao, 2022）. How to effectively carry out the practical activities of the course and cultivate the scientific thinking ability and innovative spirit of normal students majoring in primary education is a practical problem that needs to be solved urgently in the teaching reform of " Natural Science Foundation " course.

3. The Characteristics and Construction of Scientific Model

The scientific model is a description or simulation of the research object in order to simplify the research problem and explore the essence of things, which is convenient for the interpretation, prediction or visualization of the research object. Scientific model and modeling are the core elements of scientific thinking and the key tools of scientific research, and all countries regard them as an important part of science education（Yao & Liu, 2023）. The important goal of science education is to promote students to think and practice like scientists, and to think and practice like scientists is inseparable from the understanding and practice of models and modeling （Wu & Xu, 2023）. The " Compulsory Education Science Curriculum Standards (2022 Edition) " highlights the importance of cultivating students ' " model cognition " literacy in science teaching, and regards model construction as an important part of scientific thinking (Ministry of Education of the People's Republic of China, 2022). The model is a simplified description and presentation of things, phenomena, processes, structures, and mechanisms. Because of its concise and clear form, it helps to promote and optimize the expression of scientific experiments and their results（Pan et al., 2022, p. 229）. The model can help students remember and explain, as an external representation of understanding phenomena or concepts, so that students can think visually. Modeling, also known as modeling, is a form of presentation of things in order to understand things. It is an important means to study the relationship between system components and component functions.

The construction of scientific model is to establish a model of ' science ', which refers to the use of material forms or thinking forms to reproduce some essential characteristics of the prototype, such as structural attributes, functions, relationships, processes, etc., according to specific scientific research purposes and under certain assumptions. Model and modeling are the basis of cognition and scientific inquiry（Sun, 1993）. They are tools that can promote students ' cognitive development and play an important role in the process of scientific learning. Different scholars have different views on the teaching of scientific modeling, but they all agree that the model, as an important way to understand the nature of science, can improve the explanatory ability and predictive ability of the model through continuous improvement and correction (Zhai et al., 2015).

Modeling teaching can enable students to understand the laws of nature by participating in the design model, production model, test model, correction model and other links, and ultimately achieve the purpose of understanding the core concepts of science and forming the necessary character and key ability. The modeling teaching process proposed by Qiu Meihong and Zeng Maoren is mainly divided into four stages (Chiu & Tseng, 2018), 1. Model development, through observation and problem determination, leads to the model; 2. Production and verification, refined model; 3. Model migration, through application and scheduling, migration model; 4. Model reconstruction, through correction and conversion, reconstruction model.

4. Case Analysis of Scientific Model Construction

On the basis of the above-mentioned scientific modeling research, the author has carried out modeling practice teaching on the " sinking and floating " unit in the " movement and force " chapter of the " Natural Science Foundation " course. Through the activities of underwater glider model making, the effectiveness of scientific modeling in practical teaching is explored.

1) Observation and determination, leading to the model

In the stage of model development, the main teaching goal is to let students know the characteristics and functions of the structure of the " Sea Wing " underwater glider, and to be able to extract relevant scientific concepts from the data. First of all, we review the concept of the chapter of motion and force, understand the characteristics of various forces, the law of force synthesis and decomposition, and understand the influence of force on the motion of objects. By playing the video clips of the ' Sea Wing ' underwater glider and showing the teaching model, students can understand that the ' Sea Wing ' underwater glider is an underwater glider completely independently developed by China and has independent intellectual property rights, and realize the value of the ' Sea Wing ' underwater glider for ocean exploration. At this stage, the following questions are raised:

What are the structural characteristics of the ' Sea Wing ' underwater glider?

What kind of trajectory does it have and what forces it is subjected to?

Through the observation and discussion of the prototype of the underwater glider in the video, each group of students can summarize the pattern of periodic motion of the ' Sea Wing ' underwater glider sinking forward (oblique downward motion) and floating forward (oblique upward motion), as well as the situation of the force. Based on the knowledge learned in the past, combined with the structural characteristics of the ' Sea Wing ' underwater glider in the real situation, and on the basis of the perceptual knowledge of the theory of motion and force, the students are guided to consolidate the relevant concepts and recognize the basic components needed for modeling. On this basis, the teacher asks the following questions:

What are the functions of each structural component of the ' Sea Wing ' underwater glider?

Can we use some simple materials to make a model that runs underwater for a period of time (able to complete a forward sinking and forward floating action)?

The above two problems mainly focus on the structure and function of the components required for modeling. For example, the ' Haiyi ' underwater glider achieves sinking and floating by adjusting its own density (gravity is greater than buoyancy, or gravity is less than buoyancy). Before making the model, each group of students are required to fully communicate and discuss, determine a model making scheme, draw a sketch, including component composition and model size, etc., and require representatives of each group to explain the rationality of model design.

2) Production and verification, analysis model

The model refinement stage mainly includes model making and model verification. The main goal of this stage is to test the feasibility of establishing the model in the first stage by means of inquiry, and to analyze the reasons that can explain the problems. Teachers distributed materials and tools for model making to each group of students, including art knife, cutting pad, ruler, chevron board (foam board with better material), pin, hook weight, double-sided glue, copper wire, transparent sink, magnet and so on. Each student is required to make an underwater glider model according to the group 's established plan. The underwater glider model made by teachers and students in advance is shown in Figure 1, and the underwater glider model made by students in class is shown in Figure 2 and Figure 3. In a task-driven manner, each student is required to test the model in a transparent large flume to complete a sinking and floating motion cycle (horizontal motion distance is required to reach more than

20 cm).

In the process of model verification, the teacher clarifies the operation steps, such as suspending the model below the horizontal plane, keeping it stationary, suddenly loosening the details, and guiding the students to record various conditions in the model verification. Some students can successfully complete the test task, but some students ' models may appear as follows : 1.After releasing the hand, the model cannot sink and float on the water surface ; 2.After the model sinks forward to the bottom of the sink, the falling object falls off, but it retreats and floats back to the surface of the water ; 3. descend vertically to the bottom of the sink, fall off, and then float vertically to the water surface ; the model can sink forward and float forward, but the horizontal distance does not reach 15cm. Teachers guide students to discuss and analyze the above generative problems, explore the scientific principles behind these phenomena, and further modify and verify the model until they pass the test task. Through the discussion and exchange of various conditions, students can deeply understand and master the influence of changes in factors such as gravity, buoyancy, and center of gravity on model motion.

3) Application and scheduling, migration model

The model migration phase includes the application and scheduling of the model. On the basis of the second stage, students are required to explore the problems in the new situation based on the understanding of the core concepts of " structure and nature of matter " and " movement and interaction of matter, " so as to promote their deep learning of scientific concepts. Problem-oriented, using the same principles in new situations, prompt deeper student reflection. Students are asked to analyze the force of the model during a certain movement. They often only consider the force in the vertical direction, that is, gravity and buoyancy, while ignoring the existence of other forces. On this basis, the teacher combines the theoretical knowledge of motion and mechanics, and puts forward the following questions:

The model slides downward from the static state, and the resultant force is vertically downward, but in fact it moves obliquely downward. Why is this?

In the process of oblique downward movement, is the model in linear motion or curvilinear motion? Why?

Discussions were held among the members of the group to inspire them to understand the reasons behind scientific phenomena in the context of cognitive conflict. Some students think that buoyancy may provide a component force in the horizontal direction for the model, which causes the model to move in the horizontal direction. This point of view reflects some students ' misconceptions about the understanding of " the direction of buoyancy is vertical upward, " which leads to a generative problem: is the direction of buoyancy of an object vertical upward? By causing students to consult data and communicate, it is further understood that buoyancy is ' independent of the shape of the object, and its direction is always vertical upward '. The teacher continues to ask: Since the combined force of gravity and buoyancy is in the vertical direction, is the model subject to other forces? Guide students to analyze the force of the model again. After full discussion, students are guided to understand that the model is not only affected by gravity and buoyancy, but also by water resistance. The synthesis and decomposition rules of the teacher 's binding force enable students to compare with the original preset trajectory, change students ' cognition of resistance, and realize that resistance is a variable, which is related to the speed of the model and the cross-sectional area of the model, that is, the larger the area, the greater the resistance ; the greater the speed, the greater the resistance ; and vice versa.

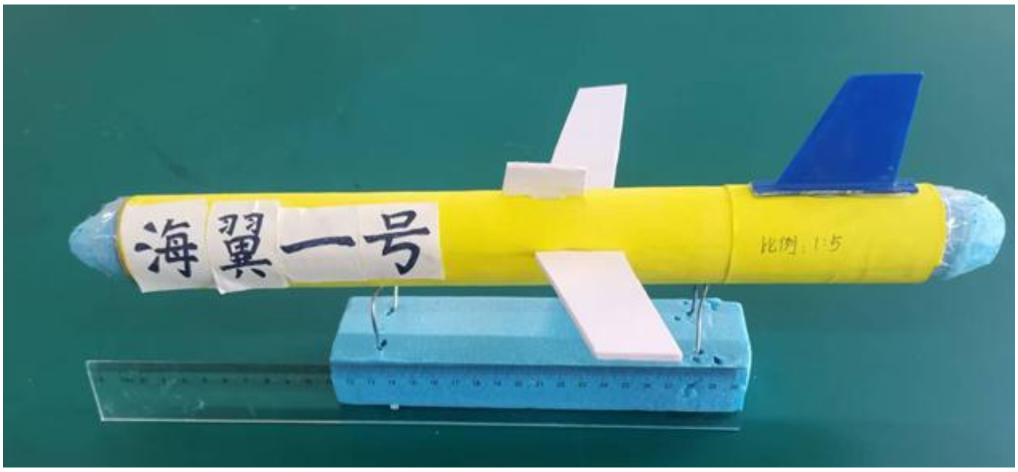

Figure 1: Underwater glider physical model classroom display

Figure 2: Top view of underwater glider model made by students

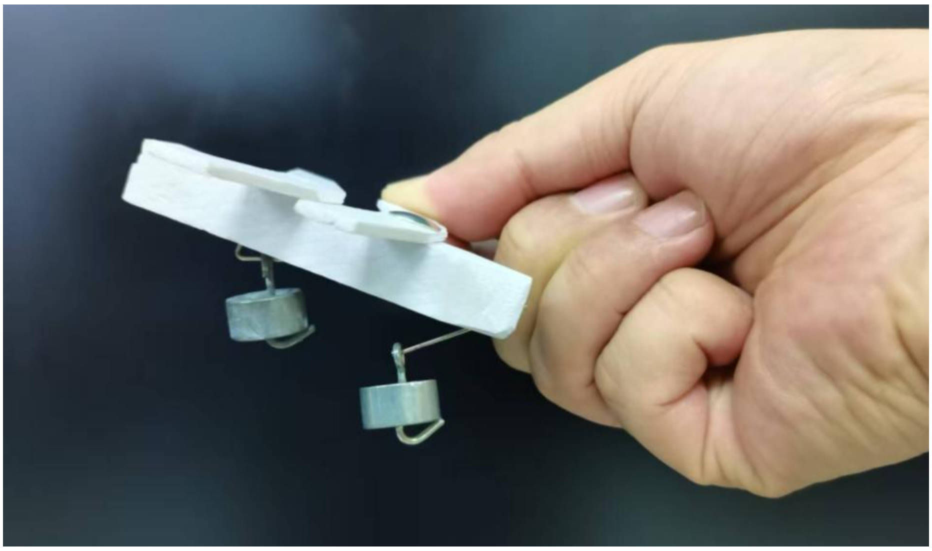

Figure 3: Side view of underwater glider model made by students

4) Modification and transformation, reconstruction model

By modifying or optimizing some components of the model, the model has a more comprehensive explanatory power, that is, to achieve the expansion and extension of the knowledge learned. Teachers should put forward new problems to modify and transform the model according to students ' interest and knowledge, and guide students to reconstruct the model. The new problems to be explored are as follows:

How to make the model slide farther in a motion cycle?

The model is required to be able to spiral down. How should the model be modified?

Even further explore, how to make an underwater submarine model or bionic fish?

Guide students to further understand from the perspective of the symmetry of the model structure, the automatic adjustment device of the center of gravity and the volume compression mechanism, so as to strengthen the study and exploration of the core concepts such as " engineering design and materialization. " Of course, the model reconstruction stage is not a stage that must be completed. Teachers can decide according to the teaching objectives and the actual situation of students.

Through the above-mentioned scientific modeling teaching process, the author 's evaluation of the chapter " Motion and Force " in the " Natural Science Foundation " course shows that students have a deeper understanding of the scientific knowledge of motion and force, learn the ability to solve practical problems, and also develop an interest in scientific exploration.

5. Discussions

Modeling provides students with the opportunity to explore and practice. Engaging students in modeling allows them to better understand key models in science and helps them understand the nature of scientific knowledge（Zhang & Zhang, 2023）. The construction process of scientific model is a process in which individuals use the existing scientific knowledge in their minds to make abstract generalizations or assumptions on objective things based on empirical facts or experimental phenomena, grasp the main factors, and transform complex research objects into simple research objects. Therefore, the construction of scientific model is not only an important part of scientific thinking, but also the carrier of the development of students ' core literacy, which is of great value to the implementation of the development of students ' core literacy.

The core of improving students ' model cognition and model practice ability is the optimization of teachers ' teaching process. The cultivation of normal university students ' scientific literacy should be gradually transferred from specific scientific knowledge to scientific world outlook, methodology, scientific essence, the relationship between science and technology, engineering technology and society. Scientific modeling is a kind of practical teaching mode. On the one hand, it needs to pay attention to the needs of scientific and technological progress and social development, pay attention to the connection between production and life, modern society and scientific development, absorb the frontier knowledge of disciplines, integrate the advanced achievements of China 's scientific and technological development into curriculum teaching, and cultivate students ' participation in social consciousness and social responsibility. On the other hand, choosing appropriate prototypes and modeling materials, making full use of modern information technology, and grasping students ' mental state, including intrinsic motivation and cognitive status of scientific concepts, will help to cultivate students ' scientific spirit and enthusiasm for thinking, cooperation and exploration.

6. Summary

Modeling is a highly practical higher-order thinking process. Modeling-based science curriculum teaching is one of the methods to understand the essence and law of objective things, which is suitable for the course content with complex and abstract concepts. Model-based instruction provides an effective pathway for helping teacher-education students understand complex scientific concepts and apply them in practice. Through hands-on modeling activities, students gain deeper conceptual insight, strengthen problem-solving skills, and develop scientific literacy. Integrating scientific modeling into natural-science coursework supports the broader goals of cultivating practical ability, inquiry-based thinking, and educational innovation in teacher preparation.

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