



# Innovative Teaching of Mathematical Modeling and Cultivation of Petroleum Talents

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**Abstract.** Mathematical modeling is the bridge between practical problems and mathematics. The course of mathematical modeling aims to cultivate the ability of students to solve practical problems. Therefore, mathematical modeling education plays an important role in cultivating high-quality talents in petroleum colleges. Firstly, the significance of mathematical modeling in the cultivation of high-quality petroleum talents is introduced. Secondly, the main problems in the teaching of mathematical modeling courses are discussed. Finally, the main measures and achievements of innovative teaching of mathematical modeling course are introduced in our school. Exploring innovative teaching of mathematical modeling with petroleum characteristics in the new period is beneficial for cultivating high-quality "dual carbon" talents.

**Keywords:** Mathematical modeling; Petroleum characteristics; Innovative teaching.

## 1 Introduction

Since 2021, the Ministry of Education has successively issued the "Action Plan for Carbon Neutrality Technology Innovation in Higher Education Institutions" and the "Work Plan for Strengthening the Construction of Talent Training System for Carbon Peak and Carbon Neutrality Higher Education". Two guiding documents put forward new requirements and deployed new measures for talent training. Faced with the challenge of insufficient guidance from the ecological civilization concept in professional education and difficulty in meeting the demand for talents in the new situation, the Xi'an Petroleum University Carbon Neutrality Future Technology Research Institute is established on March 25, 2024. The Secretary of the Party Committee of the university, Chang Jiang, pointed out that as a higher education institution with a glorious tradition of promoting oil and serving the country, it is the responsibility and mission of the university to deeply participate in national strategies, ensure national energy security, and serve regional economic development. The university should focus on the talent cultivation goals of green and low-carbon, and incorporate the concept of green and low-carbon into education and teaching.

Mathematical modeling is the use of mathematical methods to solve practical problems, which can cultivate students' ability to transform mathematical models into

practical problems[1], use computers to solve mathematical problems, and develop students' writing skills[2]. Therefore, mathematical modeling and mathematical modeling competitions have received widespread attention. Mathematical modeling, as an important method and tool, can help students better understand and solve practical engineering problems, laying a solid foundation for their career development. Oil is known as the 'blood of industry', and as Chinese economy continues to recover and improve, the demand for oil is increasing day by day[3]. Therefore, it is very necessary and important to introduce mathematical modeling into the process of cultivating petroleum talents. This article will analyze the significance of mathematical modeling in the cultivation of petroleum talents, explore the main problems in teaching, and explore the main measures for innovative teaching in mathematical modeling courses, in order to provide reference and inspiration for the cultivation of petroleum talents.

## **2 The Significance of Mathematical Modeling in the Cultivation of High-Quality Petroleum Talents**

The cultivation of petroleum engineering talents is crucial for the development of the petroleum industry. With the continuous advancement of technology and the continuous development of the petroleum engineering field, the demand for petroleum talents is increasing day by day. Many basic research related to "dual carbon" and key technologies for carbon reduction, such as green development, low-carbon utilization, and pollution reduction of fossil fuels, require a group of excellent petroleum talents. As the cradle of petroleum talent cultivation, it is particularly important for petroleum universities to cultivate high-quality petroleum talents.

Many problems in the petroleum industry can be solved through mathematical modeling, such as oil well productivity and reserve evaluation in oilfield exploration and development. By establishing mathematical models, underground oil reservoirs can be described and various parameters in exploration and development can be analyzed and optimized. Mathematical modeling, as an important method and tool, can help students better understand and solve practical engineering problems, laying a solid foundation for future work[4]. The significance of mathematical modeling in the cultivation of high-quality petroleum talents is as follows:

(1) Cultivate students' mathematical modeling awareness and apply it to work and study

Confucius said: "Those who know are not as good as those who are good, and those who are good are not as good as those who are happy. The process of mathematical modeling can extend students' learning scope to their familiar work and study. After learning the Analytic Hierarchy Process, students no longer have to worry about whether to take the postgraduate entrance examination, go to China National Petroleum Corporation, or go to China National Offshore Oil Corp when they graduate. The complex inner activities can be qualitatively described using mathematical methods, allowing students to feel the wisdom and beauty of mathematics.

(2) Developing students' ability to analyze and solve problems

By participating in mathematical modeling competitions and practical cases, stu-

dents can gain a deeper understanding of complex problems in petroleum engineering. Optimize the design of processes such as water injection, fracturing, and enhanced oil recovery in oil fields to improve their production efficiency and economic benefits. Students can establish mathematical models by consulting materials and solve them using mathematical software such as Lingo, Matlab, SPSS, Python, etc. Through the above training, students can develop their ability to analyze and solve problems. Mathematical modeling lays a solid foundation for their participation in petroleum related university science and technology innovation projects and future scientific research[5].

### (3) Cultivate students' team spirit

Team spirit is a collaborative work ethic. After all, one's strength is limited, and having team spirit is a quality that people must possess. Mathematical modeling problems come from reality and are difficult, which requires everyone to cooperate with each other in order to submit a satisfactory answer[6].

## **3 The Main Problems in Teaching Mathematical Modeling Courses**

### (1) The teaching content emphasizes mathematical theory over model background

Mathematical modeling classes are generally taught by mathematics teachers, covering topics such as mathematical knowledge, basic models, and past exam questions. Mathematics teachers generally pay more attention to the derivation of mathematical knowledge and the explanation of basic models, without emphasizing the background and practical significance of the models.

### (2) Lack of enthusiasm in students' learning process

Mathematical modeling problems originate from reality, involve a wide range of areas, and have a variety of methods to solve them. They also require familiarity with computer programming, which determines the difficulty of mathematical modeling courses and a lack of enthusiasm for students to learn[7].

## **4 The Main Measures for Innovative Teaching in Mathematical Modeling Courses**

In response to the typical problems encountered in the teaching of mathematical modeling courses, our school has carried out beneficial reforms in teaching content, teaching mode, and ideological and political education.

### **4.1 Selected Petroleum Characteristic Cases to Stimulate Students' Learning Enthusiasm**

In mathematical modeling teaching, choosing appropriate modeling problems can not only attract students' attention, but also enhance their interest in learning, while also experiencing the application of textbook knowledge in practical problems. Our school

focuses on selecting case studies of petroleum characteristic modeling courses, so that students can experience a sense of pride in applying what they have learned and stimulate their research interest.

As shown in question B of the 2021 Liaoning Province College Student Mathematical Modeling Competition, "Oil Leakage Accident in Penglai 19-3 Oilfield in Bohai Bay". Oil spills occur frequently during offshore oil extraction and transportation. After an accident occurs, the spilled oil will quickly spread outwards and form an oil film. There are five platforms in the Penglai 19-3 oilfield of Bohai Bay, and the oil leakage incident occurred on two of them. The research content of this issue is as follows:

(1) Assuming there is only one leakage point, considering changes in wind speed, water flow, and oil film density, establish a mathematical model for the diffusion law of oil leakage;

(2) Assuming there is only one leakage point, infer based on data and determine the specific area of the leaked oil;

(3) Determine the optimal location and minimum number of land monitoring stations based on the actual leakage point situation.

The above-mentioned characteristic cases are driven by oil field oil leakage accidents, guided by the needs of oil companies, comprehensively analyze practical problems, and provide more accurate solutions for oil field oil leakage accidents.

In recent years, China Undergraduate Mathematical Contest in Modeling (CUMCM) and Nation Post-Graduate mathematical Contest in Modeling have involved real oil characteristic modeling questions, including:

(1) Geological exploration drilling layout problem (Problem B of the 1999 CUMCM);

(2) Identification of displacement of oil storage tanks and calibration of tank capacity tables (Problem A of the 2010 CUMCM);

(3) Layout of oil pipelines (Problem C of the 2010 CUMCM);

(4) Modeling of Gasoline Octane Number (Question B of the 2020 Nation Post-Graduate mathematical Contest in Modeling).

## **4.2 Emphasize the Combination of Theory and Practice in Teaching Mode**

(1) Establish a mathematical modeling club and website with petroleum characteristics

For freshmen, the mathematical modeling competition is promoted through exhibition boards, lectures, online platforms and other forms. In the Mathematical Modeling Club, the old lead the new, organizing exchanges of mathematical modeling experience in their spare time, and inviting award-winning students to share their competition experiences, so that new students have a basic understanding of mathematical modeling. Students can also share resources and upload their learning resources to online platforms.

(2) Promoting education through competition, integrating competition and education

Using engineering problems in the petroleum field, classic mathematical modeling cases, and real mathematical modeling problems as examples, cultivate students' creativity in solving practical problems. Summarize the problem-solving strategies and typical algorithms of past mathematical modeling competitions, and provide students with enhanced training. The mathematical modeling team provides centralized training and guidance to students during summer vacation and spare time, focusing on different modules of the mathematical modeling course and past exam questions. Invite experts and professors in the field of mathematical modeling from both inside and outside the school to hold multiple lectures for participating students.

Organize students to participate in various levels of mathematical modeling competitions, such as CUMCM, the "Numerical and Dimensional Cup" Undergraduate Mathematical Contest in Modeling, the Asia Pacific Undergraduate Mathematical Contest in Modeling, and the American Undergraduate Mathematical Contest in Modeling. Through these teaching and competition exercises, not only can students feel the solutions to practical problems, but it can also stimulate their sense of satisfaction in applying what they have learned.

### (3) Innovate teaching methods and combine multiple teaching modes

The teaching of mathematical modeling theory is student-centered, where the teacher first raises questions, guides students to participate in discussions, and then fully explains mathematical model cases and past exam questions. Conduct "individual learning and group discussion" as a modeling group, that is, basic knowledge of "individual learning", and conduct "group discussion" on research questions. During the summer training, every 7 days is a cycle, with the instructor providing theoretical explanations for 4 days and assigning a modeling problem to the students for the remaining 3 days. Three people engage in exploratory discussions for 3 days and form teams to complete modeling assignments. Each team selects one person to present their defense and instructor propose improvement plans.

For question B of the 2021 Liaoning Province Undergraduate Mathematical Contest in Modeling, "Oil Leakage Accident in Penglai 19-3 Oilfield in Bohai Bay," after discussion between students and teachers, it was decided to abstract the leaked oil at sea as a group of particles and use particle swarm optimization algorithm to solve the problem. Randomly initialize particle states, with each particle escaping towards areas of sparse density. In the question, it is necessary to determine the location of the oil leakage point, which can be divided into two situations:

(i) the oil leakage point has been leaking continuously, and the particle density of the oil at the leakage point is still the highest. The k-means clustering algorithm can be used to obtain the location of the oil leakage point;

(ii) The oil leakage point has stopped leaking, and the oil spills are distributed in a strip shape. The position of the oil leakage point is obtained using a neural network.

### (4) Modularize teaching content and collaborate with teams for teaching

Summarize the problems, problem-solving strategies, and typical algorithms of previous mathematical modeling competitions into several knowledge points or practical points, and integrate them into the teaching content of mathematical modeling courses. Design a series of module courseware to form a teaching case library for mathematical modeling. Assign teaching modules to the teachers of the mathematical

modeling team based on their professional backgrounds and strengths in their respective disciplines. The modeling team held multiple lectures and centralized training guidance for participating students during summer vacation and spare time, laying a solid foundation for achieving excellent results.

### **4.3 Exploring Ideological and Political Education to Enhance Students' Sense of National Pride**

Curriculum ideological and political education is an organic unity of knowledge transmission and value guidance. In the process of knowledge transmission, it permeates patriotism, legal literacy, moral conduct, professional competence, and scientific spirit. It is not a simple combination of "curriculum" and "ideological and political education", but rather the infiltration of "ideological and political education" into the "curriculum". Compared to other courses, the content of mathematical modeling is diverse, making it easier for teachers to integrate ideological and political content into the teaching process[8]. At present, researchers have made some explorations in the ideological and political aspects of mathematical modeling courses [9-10].

#### **(1) Cultivate a strong sense of national pride and honor**

In previous years' national competitions, there have been multiple references to "great power heavy equipment", such as the 2021 and 2014 CUMCM, where question A involved the adjustment of the "FAST FAST" active reflector and the soft landing of the "Chang'e-3" spacecraft, respectively. When explaining question A of the 2021 CUMCM, the world's largest single aperture spherical radio telescope, FAST, was showcased through a video, introducing the "father of FAST" Nan Rendong and learning from his scientific spirit and patriotic feelings of bravely undertaking the great task of national rejuvenation. Introduce the heroic deeds of Chinese astronauts and the tremendous achievements of China's aerospace industry when explaining the Question A of 2014 CUMCM. Through relevant competition questions, we aim to enhance national pride and help students understand that 'no heavy weapons, no great country'. For example, in the presentation of the Question A of 2003 CUMCM, "SARS transmission problem", the model was applied to the study of the COVID-19, combined with the comparison of prevention and control policies, highlighting the strong country and the people centered concept, and infiltrating patriotism.

#### **(2) Strengthen professional sentiment**

When explaining the B question of the 2021 Liaoning Province Undergraduate Mathematical Contest in Modeling, "Oil Leakage Accident in Penglai 19-3 Oilfield in Bohai Bay," the heroic deeds of Iron Man Wang Jinxi and the development history of China's oil extraction are introduced, strengthening professional sentiment while infiltrating environmental protection awareness. When discussing the issue of oil pipeline layout in the 2010 CUMCM, we will talk about the construction of crude oil pipelines, refined oil pipelines, and natural gas pipelines in China, as well as the enormous economic benefits and social significance these pipeline infrastructure have brought to China's development, inspiring students to actively participate in the country's energy construction.

#### **4.4 Reasonably Arrange Teaching Content based on Professional Characteristics**

Reasonably select textbooks and arrange teaching content based on the characteristics and needs of the profession. Mathematical modeling is a compulsory course for mathematics majors. Mathematics majors have a solid theoretical foundation in mathematical modeling, so in modeling training, we focus more on strengthening programming and real problem training to avoid students only being able to talk on paper. Computer science students have strong programming abilities. Considering the characteristics of their major, modeling training mainly teaches modeling methods and their applications, while also applying computer knowledge in a timely manner. It is crucial to flexibly adjust the content of course teaching based on the characteristics of different majors for student modeling competitions.

### **5 Achieve Results**

The innovative teaching methods of the above mathematical modeling course have been applied to classroom teaching, achieving certain results, mobilizing students' enthusiasm for learning, enabling them to recognize the purpose of mathematical modeling, and attaching importance to the practical operation and use of algorithms. Under the careful guidance of the mathematical modeling team, our school's students achieved excellent results in the mathematical modeling competition. In the past 5 years, our university has won 3 national second prizes, 21 provincial first prizes, and 94 provincial second prizes in the undergraduate category of CUMCM; There are 2 first prizes and 2 second prizes in the American Undergraduate Mathematical Contest in Modeling and the awards have shown an increasing trend year by year. The achievements have encouraged and motivated more students to participate in mathematical modeling courses and competitions, forming a good learning atmosphere. Students who have participated in modeling training unanimously expressed that mathematical modeling has been of great help to them, allowing them to learn a lot of knowledge, such as the ability to analyze and solve problems, programming skills, and writing skills. As math major student Wang Xinyi said, 'One competition, lifelong benefits.' Through communication with her advisor, she fell in love with mathematical modeling and plans to participate in the American Undergraduate Mathematical Contest in Modeling in the future.

### **6 Conclusion**

The mathematical modeling course aims to cultivate students' ability to solve practical problems, explore reforms in mathematical modeling education and teaching in petroleum related universities, and cultivate high-quality "dual carbon" talents. This article introduces the significance of mathematical modeling in the cultivation of high-quality petroleum talents, explores the main problems in the teaching of mathe-

mathematical modeling courses, and discusses the main measures of mathematical modeling courses.

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