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RESEARCH ORIENTED TEACHING REFORM OF HIGHER MATHEMATICS COURSE IN PETROLEUM SCIENCE

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Abstract

Higher mathematics is an important public basic course for the freshmen of science and engineering university.In order to solve the problem of traditional teaching, a research oriented teaching reform of higher mathematics course in petroleum science was carried out from the aspects of teaching cases design, classroom teaching, practice teaching, and assessment methods. The teaching reform was proven effective and successful by the teaching practice of freshman mathematical experimental classes of Yangtze University in recent years. It improve the students' abilities of understanding and application the mathematical knowledge. It also helps students to learn the specialized knowledge in the field of petroleum science easier in the future.

Keywords:Teaching Reform;Higher Mathematics;Calculus;Research Oriented Teaching;Petroleum Science.

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1. Introduction

Compared with the traditional teaching which transfers the knowledge from teacher to students directly, the research oriented teaching is a new teaching mode which combine teaching, researching, and studying together, aiming at cultivating students' innovative spirit and ability [1].In the research-based teaching, teachers act as guiders, guiding students to put forward problems based on learned knowledge and to analyze problems during study. Students could learn how to solve the practice problems and become a self-developing and creativeperson [2].

Higher mathematics is an important public basic course for the freshmen of science and engineering university. It is not only an important carrier for cultivating students' logical thinking and learning ability, but also an important foundation for students to follow up on their professional knowledge. It is also an important mathematical tool for further study and research [3]. Currently, most teachers of universities are still using the traditional teaching mode, which is "teacher speaking, students listening". It is not good for cultivating the students' independent thinking ability and innovation ability of mathematical knowledge [4]. Therefore, it is necessary to employ new teaching mode to change the passive acceptance of students, and to develop students' thinking and application ability. Petroleum science disciplines are the characteristic disciplines of our university, which include the Geophysics, Geology, Petroleum Engineering, and other petroleum-related specialties. There are about 2,000 students in the Petroleum science disciplines in our university. The higher mathematics is a critical important mathematical tool for the petroleum science.

In this paper, we present the methodology and the teaching case of research oriented teaching of the higher mathematics in petroleum science. The teaching practices show that our research oriented teaching reform is successful and effective.

2. Methodology

2.1 Framework

The research oriented teaching has three main parts, research on teaching syllabus, teaching including classroom teaching and practice teaching, and assessment method. The teaching part is the most important one of the research oriented teaching. It contains several teaching cases. The teaching method for each case consists of three sub-modules, Design which means teacher put

forward the problem need to study and solve, Implement which means students study and solve the problem put forward by teacher, and Reflection which means teacher and students discuss and summary together. The framework of research oriented teaching is illustrated in Figure 1.

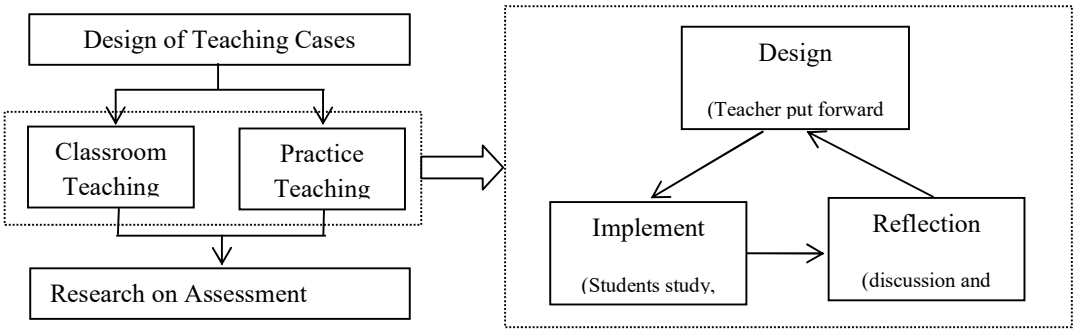

Figure 1. *Framework of research oriented teaching*

2.2 Design of Teaching Cases

We design the research-based teaching cases, which are listed in Table 1, according to the knowledge system of higher mathematics and the characteristics of petroleum science.

Table 1. *The teaching cases for the research oriented teaching of higher mathematics*

No.	**Knowledge**	**Research Oriented Teaching Case**
1	Functions and Limits	Limitation in petroleum science
2	Derivative	Edge detect for the potential anomaly
3	Integral	Use integral to calculate gravity anomaly
4	Spatial Analytic Geometry	Scientific visualization, how to calculate the interface of two curve space
5	Differential Calculus of Multivariate Functions	Gradient descent method in the optimization in petroleum science
6	Integral Functions of	Understand the Maxwell Equations

	Multivariate Functions	
7	Ordinary Differential Equation	Use ODE to solve the geophysical forward problem
8	Infinite Series	Fourier Series and its application

2.3Classroom teaching

(1) Design

In the problem design stage, teachers put forward a problem, which is associated to the learned knowledge and new knowledge, based on the teaching plan and classicalteaching case. The students could active think about and solve the problem.

(2) Implement

In the implementation stage, the teacher should guide the students to divide into groups forming learning atmosphere and discussion. The students in a same group cooperated each other. At this stage, teachers act as collaborators, coordinators, counselors and inspectors, who identity students Learning process to track.

(3) Reflection

In the reflection stage, both students and teachers should reflect deeply. The teachers mainly reflect on the problems in the research based learning and the organization discussion. The students summarize the obtained knowledge and method, abstract them into mathematical theory and methods, and form a comprehensive knowledge system gradually.

2.4 Practice teaching

Although mathematics does not like the physics, chemistry and specialized courses which has many experiments, We could add practice teaching in the higher mathematics course, such as digital experiments and mathematical modeling, which not only could help students to understand the learned knowledge, but could cultivate the students' mathematical practice ability. Digital experiment is a new experimental method, which is used to help students to master knowledge and solve the mathematical problems using mathematical software. The purpose of

digital experiment is to improve the enthusiasm of students to learn mathematics and the students' abilities to understand and solve practical problems with the knowledge of mathematics and computer technology. It is the effective way for the students to understand the laws and skills of mathematics [5].

Matlab [6] is a useful and open source free mathematical software, which has the advantages of easy learning, powerful graphic functions. Students try to use Matlab to solve the mathematical problems after they understand the basic mathematical concept. It is an effective way for the students to practice the their mathematical knowledge using Matlab to do the digital experiment [7].

2.5 Assessment method

The focus of research oriented teaching is the teaching process rather than teaching results. Therefore, the evaluation method should be changed from summative evaluation to procedural evaluation [8]. The evaluation of students should also be transformed from a final closed-book examination to a diversified assessment mode. It should be a comprehensive evaluation from aspects of basic knowledge, basic ability, basic methods, and basic ideas, and be carried out during the whole implementation of research oriented teaching.

We designed a assessment method for the research oriented teaching of higher mathematics, which consisted in 3 parts, Attendance, Assessment for the study process, and Final Exam, listed in Table 2.

Table 2. *The assessment method of the research oriented teaching*

Item	**Description**	**Scores**
Attendance	A: ≥ 90%; B: ≥ 75; C: ≥ 60; D:<60	10
Assessment for the Study Process	Homework	10
	Quiz (4 times)	20
	Grouped research based study (6 times)	40
Final Exam	Traditional Final Exam	20

Total Score		100

3. Examples of Research Oriented Teaching Cases

3.1 Edge detect for the potential anomaly

In mathematics, a partial derivative of a function of several variables is its derivative with respect to one of those variables, with the others held constant (as opposed to the total derivative, in which all variables are allowed to vary). Partial derivatives are used in vector calculus and differential geometry [9].

In general, it is difficult to understand the concept of partial derivative of a function for the freshman, letting alone how to use it. However, in the field of geophysics, the partial derivative is often used to detect the edge of potential anomaly.

The total horizontal derivative (THDR) of potential field data is defined using partial derivative as follow [10],

$$THDR(x,y)=\sqrt{\left(\frac{\partial f(x,y)}{\partial x}\right)^2+\left(\frac{\partial f(x,y)}{\partial y}\right)^2} \qquad (1)$$

Model 1 is a single density model of a verticalhexahedron with the aim to test the peak sharpeningeffect of the method. Model parameters are: 80 mwidth in the east-west direction, 160 m length in thenorth-south direction, and a burial depth of 10 to 50m. Figure 2 [10] shows the gravity data and its edge recognition result using THDR.

In the Figure 2, the actual boundary the geology body is marked as black rectangle.We can not locate the edge of geology body from gravity data directly, shown in Figure 1(a). However, we can locate edge of geology body from the THDR of the gravity data easily, as shown in Figure 1(b). From this example, students can understand the concept and usage of the partial derivative much more easily.

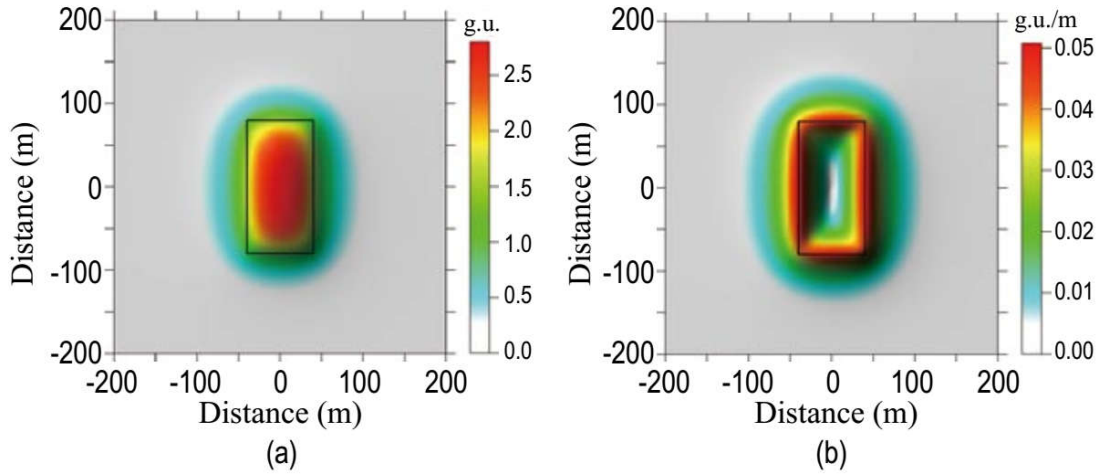

Figure 2. *Gravity data and its edge recognition result using THDR*

(a) *Gravity data; (b) edge recognition result using THDR*[10]

3.2 Understand the Maxwell Equations

It is hard to understand the Stokes formula and Gaussian formula since it involves a number of variables. We guide the students to memories the electromagnetic field learned in the physics at high school, and to find and read relative information about electromagnetic field theory. In fact, in geophysical exploration, the electromagnetic field of a particular field source is calculated when necessary. The theoretical basis of the calculation is Maxwell Equations, and Maxwell Equations are closely related to the Stokes formula and the Gauss formula. The differential form of Maxwell's equations is:

$$\nabla \times \mathbf{H} = j_0 + \frac{\partial \mathbf{D}}{\partial t} \tag{2}$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{3}$$

$$\nabla \cdot \mathbf{B} = 0 \tag{4}$$

$$\nabla \cdot \mathbf{D} = \rho_0 \tag{5}$$

Stokes formula is:

$$\iint_S (rot\mathbf{A})_n ds = \oint_\Gamma \mathbf{A}_\tau dl \tag{6}$$

Let $\mathbf{A}$ in Eq. (5) be the electric field $\mathbf{E}$, Substituting equation (3) into formula (6), we can get:

$$-\iint_S \frac{\partial \mathbf{B}}{\partial t} ds = \oint_\Gamma \mathbf{E} dl \qquad (7)$$

The physical meaning of Eq. (7) is the Faraday's law of induction in high school: the induced electromotive force in a closed coil is proportional to the rate of change of the magnetic flux passing through the coil.

Let $\mathbf{A}$ in Eq. (6) be the magnetic field $\mathbf{H}$, Substituting equation (3) into formula (6), we can get:

$$\oint_\Gamma \mathbf{H} dl = \iint_S \left(j_0 + \frac{\partial \mathbf{D}}{\partial t} \right) ds = i_0 + \iint_S \left(\frac{\partial \mathbf{D}}{\partial t} \right) ds \qquad (8)$$

The physical meaning of Eq. (8) is the generalized law of the ampere-loop law learned by high school: the line integral of the magnetic field strength H along any closed curve is equal to the full current passing through the area defined by the curve. Correspondingly, the concepts of divergence, rotation in higher mathematics can be understood easily. To adopt this model of teaching, students will have a preconceived feeling when they learn the professional courses in the future.

4. Conclusion

A research oriented teaching reform of higher mathematics course for the petroleum science was carried out from the aspects of teaching cases design, classroom teaching, practice teaching, and assessment methods. After the methodology was proposed systemically, several teaching cases of the higher mathematics in the petroleum science are described in detail as examples. The teaching reform was proven effective and successful by the teaching practice of freshman mathematical experimental classes of Yangtze University in recent years. It improve the students' abilities of understanding and application the mathematical knowledge. It helps students to learn the specialized knowledge in the field of petroleum science easier in the future.

Acknowledgments

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