Innovative Research Courses for Materials Science Specialty
Based on Problem-based Learning Mode

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Abstract. Material science and engineering is an interdisciplinary subject that requires students not only
have a deep understanding of materials, but also learn to analyze and solve practical problems in various
cross-disciplinary fields. Problem-based learning (PBL) is a student-centered, problem-oriented teaching
method. Innovative research short courses based on the PBL teaching mode for undergraduate students
majoring in materials science can highlight the practicability and advancement of the course. This paper
highlights how to mobilize students’ learning enthusiasm and cultivate students' comprehensive
innovation ability in combination with the characteristics of material science, as well as the teaching
content. The reform of teaching methods and assessment methods is also discussed.

Introduction

Material science and engineering is an interdisciplinary subject which studies the
interrelationship among the preparation or processing technology of materials, the microstructure of
materials and the macroscopic properties of materials. Material science involves the nature of
matter and its integrated application in various fields of science and engineering. With the vigorous
development of science and technology, material science has a rapid development trend in the
interdisciplinary fields of physics, chemistry, biology, electronic informatics and other disciplines.
In view of the extensive application of materials science, students majoring in materials science
need to systematically study the basic knowledge and principles of materials, and at the same time
need to have a deep understanding of the nature of materials applied in various scientific fields, and
also learn to analyze and solve practical problems in various cross-cutting fields. All of these have
improved the difficulty of professional knowledge of students majoring in materials. Higher
education in China is dominated by traditional teaching mode, and students' learning process is
passive, which makes it difficult to explore proactively.

Innovative research course is a characteristic undergraduate teaching mode in our university. It
emphasizes academic, research and practice. It provides a good exploration direction for creating an
atmosphere of inquiry learning and independent learning, stimulating students’ innovative thinking,
and cultivating students' innovative spirit and practical ability. However, how to organize the short
course of innovative research, how to combine teaching with practice, and how to cultivate students’
innovative ability? These questions deserve teachers’ further consideration and discussion.
Problem-based learning (PBL) is a student-centered, problem-oriented teaching method. It was first
initiated by Professor Barrows and Professor Tamblyn in McMaster University, Canada, which has
become a popular teaching method in the world. The PBL teaching mode is aimed at solving
problems, highlighting the main position of students in teaching, mobilizing students' learning enthusiasm and cultivating students' comprehensive ability.

In this study, we draw lessons from the international popular PBL teaching mode and creatively
apply it to our university's characteristic short courses for innovative research. By analyzing the
characteristics of material science students’ professional knowledge, the short courses of innovative
research aim at solving problems based on professional theoretical knowledge. This paper
highlights how to mobilize students' learning enthusiasm and cultivate students' comprehensive
innovation ability in combination with the characteristics of material science, as well as the teaching
content. The reform of teaching methods and assessment methods is discussed.
Course Scheme and Characteristics

Innovative research courses are taught in small classes, including thematic seminars and scientific research projects. Thematic seminar short courses are devised by teachers to formulate academic topics or scientific issues related to the subject and specialty. Teachers first guide students to search literatures and documents around the subject or problem, and then organize students to study theoretical knowledges. Finally, a student-centered small group seminar was held. Teachers participated in the student-centered group seminar by listening in and assessing the performance of each student. This course focuses on training students' ability of literature review, academic research, oral expression and creative thinking. The main feature of the short course of scientific research projects is to transform teachers' scientific research projects into curriculum teaching.

The short course of scientific research projects are based on scientific research projects, which integrate scientific problems, advanced technologies and scientific research methods into the curriculum teaching, so that students can combine their theoretical knowledge with practice, complete a preliminary exploration of a scientific research project through hands-on experiments, and thoroughly understand the theoretical knowledge in books in the process of practice. In the teaching process of the course, students are taught the methods and skills of innovative research, and guided to complete the whole learning process of combining theory with practice, which includes topic selection, literature retrieval, research plan formulation, practical research process and thesis writing.

Teaching Content Reform

According to the characteristics of the short course of innovative research and the frontier research topics of materials specialty, the reform of teaching contents mainly includes the following three aspects: what, why and how.

(1) What? In the early stage of the course, teachers will design academic topics or scientific problems related to the subject or specialty. Students can find out what the theoretical concept is by searching literatures and documents themselves, and tell others what the theoretical concept is through group discussions. This method helps to cultivate students' ability of literature review and oral expression.

(2) Why? In the traditional teaching mode, students are accustomed to absorb theoretical knowledge directly from the outside world, and seldom take the initiative to think about the internal relationship between concept A and concept B. What teachers need to do is to guide students to actively think about the internal relationship between theoretical knowledge and understand why A situation will lead to B. This method helps to strengthen students' in-depth understanding of theoretical knowledge, and cultivate students' innovative thinking ability.

(3) How? In this stage, teachers will guide students to make research plans, conduct experimental research on scientific problems in the laboratory, and finally complete the paper writing. This method helps students to use the skills acquired in the first and second parts of the teaching content to solve the problem of "how to do".

Teaching Methods Reform

The combination of various teaching methods can help to mobilize students' learning enthusiasm, enhance students' classroom attention and improve students' ability to accept knowledge. The reform of teaching methods includes the following aspects. First, make full preparations before class. Teachers should make good preparations before class, publish discussion topics and research background materials in advance, and guide students to think and prepare before class. For example, the teacher designed several frontier research topics of materials science before the beginning of the course, and then briefly introduced the background and application prospects of these professional research fields, which would help to enhance students' interest in learning. At the same time, the teacher put forward some professional knowledge points for theoretical explanation, pointed out the
scientific issues existing in the subject, and guided students to conduct literature research in advance for discussions in class. Second, strengthen the combination of theory and practice. Students often find it difficult to understand the abstraction in the study of theoretical knowledge. Taking advantage of the flexibility of the short-term teaching place of innovative research, teachers can lead students to visit the laboratory and to design and verify the experiment, which can greatly improve students' understanding. For example, in order to explore the influencing factors in the process of film growth, teachers can guide students to design different experimental conditions and seek solutions from the experimental process. Third, pay attention to summary. At the end of each topic discussion, the teacher organizes the students to summarize the topic in time, which can help students straighten out the logical relationship between the various knowledge, and cultivate the students' ability to solve problems. By summing up the scientific problems together, students can consolidate their knowledge, think comparatively and innovate. For example, after discussing the growth process of thin films prepared by vacuum deposition, the teacher could organize students to list various influencing factors and guide them to think about the growth mode of thin films prepared by solution method.

**Reform of Assessment Methods**

The assessment method of a course plays an important role in determine how students learns the course. In view of the reform of teaching contents and methods mentioned above, we divide the assessment methods of innovative research courses into three parts. The first part is homework assignments, mainly including homework and literature research, accounting for 30% of the total score. Usual homework is mainly composed of short answers and literature review. This way can examine students' thinking and ability to analyze problems. The second part is students' discussions and experiments, accounting for 30% of the total score. This part of the assessment is to let students put forward their own solutions to scientific problems in groups and carry out experimental verification. In this process, the students fully exchanged their views on the topic, exercised their speculative ability and cooperation spirit, and also trained their hands-on ability and experimental skills. The third part is the course paper and oral report, accounting for 40% of the total score. Students independently complete the course summary papers, including literature research, experimental design, results analysis, etc., and finally select a topic for oral presentation and exchange with the whole class. This part of the assessment not only exercises the students' ability to analyze and summarize, but also cultivates the students' ability to write papers and demonstrate, and also plays a role in consolidating professional knowledge. The combination of the three assessment methods avoids the tedious simplicity of traditional examinations, integrates theory, application and innovation, and cultivates students' professional quality, scientific research ability and innovative spirit in an all-round way.

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