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Research on Teaching Reform of Basic Experiment Course of Material Science

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Abstract: This paper expounds the teaching model that integrates quality education, knowledge impartation and ability cultivation. In view of the current situation and existing problems, the focus of teaching research lies in how to stimulate students' enthusiasm and initiative, promote their knowledge construction, and develop their thinking and comprehensive abilities. The basic experiment of material science is an auxiliary teaching module of the theoretical course. It is a compulsory practical training course for materials science related majors. However, there are problems in the current basic experimental teaching of materials science, such as outdated teaching content, disconnected from theoretical knowledge, and a single assessment method .Based on the development of contemporary materials science and the direction of cultivating applied talents, we improve the experimental teaching methods, experimental types, and evaluation methods. It aims to enhance students' comprehensive ability, innovation ability, ability to solve practical engineering problems. The teaching practice proves that the reform of the teaching pattern improves the teaching quality, broadens the breadth and depth of the course, and favors improving students' comprehensive quality and ability. It is worthy of continuing to do further research, application and promotion.

1. Introduction

Since entering the 21st century, with the rapid development of the global economy, there has been a further increase in demand for applied talents and practical vocational talents. Many universities have seized this opportunity to improve the quality of applied talent training. How to cultivate talents that meet the needs of social development is a challenge faced by every applied university. Many institutions have carried out innovative and practical reforms in the construction of applied undergraduate education, focusing on school positioning, talent cultivation models, major settings, course systems, and practical teaching stages, achieving certain results. However, there are still some issues that need to be addressed. Therefore, we need to change our teaching concepts, reform teaching models, innovate teaching methods, and comprehensively enhance students' practical abilities and comprehensive qualities.

2. Current situation of experimental teaching of materials science

The experimental teaching of materials science is a practical component that complements the teaching of the Fundamentals of Materials Science course, aimed at enhancing students' practical abilities and innovation skills, with the goal of cultivating applied and innovative talents.However, previous experiment of material science fundamentals lacked innovation and comprehensiveness, mainly focusing on verification experiments with relatively outdated teaching methods and approaches. Therefore, to align with the goal of cultivating applied talents, it is imperative to reform the teaching content and methods of the course to better leverage its role in enhancing theoretical learning and practical skills, and to explore effective ways to cultivate talents with practical abilities and innovative consciousness[1-2] . Currently, teachers in laboratory classes still follow a pattern where they lecture, students listen, then teachers demonstrate while students perform the experiments. The teaching methods are relatively dull, with a strong focus on teaching objectives during classroom instruction. The teaching approach is rigid, and the classroom atmosphere lacks vitality. When explaining experimental principles to students, teachers often emphasize knowledge and experimental skills but neglect effective guidance. As a result, students fail to fully understand the principles, making the experimental teaching lack depth and vitality. Knowledge is merely imparted without guiding students' thinking. During experiments, there is insufficient communication and collaboration with students, leading them to miss out on the mysteries of experiments and the joy of successful operations. This can result in students becoming disinterested in attending lab sessions.

Currently, the foundational materials science laboratory course mainly involves verification experiments. Most of these experiments are conducted step-by-step under the guidance of lab instructors, following the experimental instructions mechanically. After completing the experiments, some students are unaware of their purpose and significance. Students lack an integrated understanding of the experimental process and related theoretical knowledge, let alone the development of independent thinking and innovation capabilities. Additionally, some experiments require repetitive operations. Students often lose interest due to repeating similar experiments and adopt a perfunctory attitude towards them. For example, one experiment involves observing various tissue samples with an atomic force microscope, where each sample follows the same observation steps. Initially, students are highly interested, but after observing two or three samples, they lose enthusiasm and hastily complete the remaining tasks. This makes it difficult for students to truly master experimental knowledge, and their subjective initiative is not fully utilized. Therefore, to address the issues present in traditional materials science foundational laboratory teaching, we have reformed the course based on our university's polymer materials engineering application-oriented talent training program. The reforms include teaching methods, experimental types, and evaluation methods, aiming to further enhance the efficiency and quality of experimental instruction.

3. Reform of experimental teaching methods

3.1 Utilize information technology to assist in experimental teaching

The way of telling knowledge in the classroom is no longer limited to the traditional blackboard and textbooks, and students have to think about some abstract content by themselves. The development of science and technology has driven the teaching aids of education, and if we want to talk about the model of organic compounds in the classroom, we can use the corresponding teaching aids to display it intuitively; Some experiments are more dangerous, or there are not enough instruments and equipment to meet the requirements of students to conduct experiments, so you can use some software to conduct virtual simulation experiments[3]. These software not only ensure the safety of students, but also fill the gaps in the classroom, and at the same time satisfy students' curiosity and deepen their understanding of knowledge.

In recent years, Chinese universities have introduced online teaching and management systems such as Chaoxing Learning Pass and Rain Classroom, providing strong support for online instruction. Using these new platforms, we can upload micro-lectures on fundamental materials science experiments, supplementary reading materials, and other resources for students to access and study at their convenience. The materials science foundation experiment course adopts a blended learning approach that combines online and offline methods, which better motivates students and enhances their ability to learn independently[4]. Before each lab session, the instructor uploads the syllabus, demonstration videos, PowerPoint presentations, and operational procedures to Learning Pass. This encourages students to complete their pre-class preparation., helping them fully understand the lab content and increasing their interest in learning[5].If students have difficulties with certain concepts, they can use micro-lecture videos like MOOC and Yun Class to clarify their doubts. Additionally, they can use communication tools such as WeChat and QQ to ask questions anytime to teachers or classmates[6].

3.2 Utilize professional data analysis software for scientific applications to enhance experimental effect

Currently, professional software commonly used in teaching includes Gwyddion, Gaussian, ChemDraw, Mercury, and Diamond. Gwyddion is a tool for data visualization and processing of scanning probe microscopy and profile measurement data, including SPM such as AFM, STM, MFM, SNOM/NSOM. It is particularly useful for general image and two-dimensional data analysis. For example, in an experiment where we observe the morphology of polymers using an atomic force microscope, students are required to use the Gwyddion software to process the surface morphology of the observed crystalline film. This not only fulfills the experimental content required by the curriculum but also teaches students to use a graphic processing software, thereby enhancing their hands-on and analytical skills. Diamond is an intelligent computer software for chemical drawing, capable of creating models of various types of crystal structures, such as linear, stick-and-ball, or space-filling forms, and polyhedral shapes. These models can be moved, scaled, and rotated as needed. Diamond allows for easy manipulation of individual atoms, bonds, and polyhedra, enabling the creation of ideal images or even animation files[7]. In the analysis of metal crystal structures using the steel ball packing model experiment, the atomic structure itself is quite abstract. We can use the software to help students identify the densely packed planes and directions of atoms in three types of crystal structures, as well as the positions and distributions of tetrahedral and octahedral voids. This helps students become proficient in the characteristics of the three types of crystal structures. Subsequently, students can stack steel balls according to the most densely packed planes to form face-centered cubic and hexagonal close-packed crystal structures. This approach allows students to vividly perceive the internal structure of crystals, making it easier for them to grasp the principles of the experiments and increasing their interest and curiosity in learning.

3.3 Reform traditional laboratory teaching to enhance creativity

Learning should be applied in practice. The fundamental purpose of education is to apply what is learned. The goal of cultivating applied talents is to ensure that students truly apply their knowledge to serve society. Therefore, we can appropriately increase practical components in experimental courses, strengthen connections with local enterprises, and lead students out of the laboratory to truly enter enterprises and workshops. This allows them to understand the current production status of businesses and address the problems they need to solve through experimental projects. This approach not only fulfills the teaching tasks of experimental courses but also enhances students' hands-on and analytical skills, encourages innovative spirit, and fosters a sense of social responsibility. It provides the country with innovative and practical talents who are specialized. Additionally, we can implement new experimental teaching models such as sending students to other universities or exchanging students with those from other universities. Through interactions and collaborations with students from different universities, it widens students' horizons, expands their scope of knowledge, stimulates their thinking abilities, and improves their creativity comprehensively.

4. Reform of experimental types

4.1 Enhance foundational verification experiments to stimulate students' initiative and experimental skills

The basic verification experiment is often explained by the teacher to the principle and content of the experiment, and the students follow the steps of the experimental textbook to operate, so that the students can be familiar with the characteristics of the basic experiment of material science as soon as possible, master the use of instruments and equipment, form standardized basic experimental skills and literacy of material science, and develop good experimental habits. In the whole verification experiment, students only operate the experiment mechanically according to the experimental process, without the process of independent thinking, which is not conducive to the cultivation of students' ability to analyze and solve problems, and also loses the original intention of the experimental course. The traditional basic verification experiments are improved, for example, the experiment of measuring the coefficient of glass line expansion, from an experimental sample to four different glass samples, to determine the difference of linear expansion coefficient under the same conditions, to understand the influence of different microstructures on the expansion coefficient of materials, and then to discuss and summarize in groups after the experiment is completed, which not only deepens the students' understanding of the principles and methods of experimental determination, but also stimulates students' interest in learning and desire to explore.

4.2 Increase the design-based and comprehensive experiments

Design-based experiments are the most enlightening teaching methods, capable of mobilizing and leveraging students' initiative and creativity. They represent the primary future direction for experimental teaching. In design-based experiments, students need to formulate their experimental plans based on projects provided by consulting relevant references, and discussing with teachers. Under the guidance of the teacher, they complete the experiment independently. For example, the newly added experiment on observing and analyzing the crystallization process and structure of crystals is a comprehensive experiment. The experiment uses knowledge from material science fundamentals, covering not only basic methods for preparing single crystals but also common analytical testing techniques for crystals. We require students to first search for relevant references, actively design experimental recipes, and formulate experimental plans. They integrate the preparation of single crystals, crystal structure characterization, infrared spectroscopy analysis into one comprehensive experiment project. Starting from raw material preparation, followed by crystal growth, and finally performance testing and structural characterization, the entire experimental process is entirely designed and operated by the students, with the experimental teacher providing only auxiliary guidance and safety supervision. By conducting such comprehensive experiments, students' initiative and enthusiasm are fully unleashed, enriching the content of experimental teaching, thereby enhancing students' overall competence and fostering their engineering mindset[8].

We enhance design and comprehensive experiments, and allow students to choose their own projects and focusing on the development of individuality. Using the online teaching management system provided by the school, we adopt a progressive experimental open management model.At the beginning of each semester, teachers publish the semester's experimental projects and times online. Students can select experiments based on their schedules and interests, design their experimental plans, and have ample time to realize their ideas. This model is similar to elective theoretical courses, where students can choose from numerous open design and comprehensive experiments that interest them and easily receive personalized guidance from instructors, overcoming time and space constraints effortlessly. Additionally, this open model provides an excellent experimental platform for students from other related disciplines, enabling those interested in materials science or planning to work in related fields to participate.

5. Reform of the evaluation methods

Abandoning the traditional 'one exam determines the level' experiment test model, we now adopt a comprehensive evaluation system that combines regular performance with exam scores. The assessment method is process-based, encompassing various forms such as lab reports, experimental procedures, and final practical exams for an overall course evaluation. Regular grade accounts for 40%, while the final practical exam makes up 60%, conducted through an experimental operation format[9].

(1) Regular grade includes lab report grades (30%) and attendance (10%). Lab report requirements: experimental purposes, experimental principles, experimental instruments, experimental procedures, raw data, data processing, graph creation, error calculation and analysis, discussion on the experiment, and proposed improvements.

(2) Examination performance involves practical tests on experimental content, where students draw lots to determine their specific experiment. Requirements during the perform experiment include seriousness, proficiency, observational skills, logical organization of the experimental process, and the ability to independently solve real-world problems.

6. Conclusions

By exploring and innovating in aspects such as teaching methods and content, it has effectively transformed the previously monotonous and dull experimental teaching approach, achieving mutual promotion and coordinated development between theoretical and practical teaching. It deepens students' understanding of basic theories of materials science, strengthens their abilities in designing experimental plans, conducting experiments, analyzing problems, and solving problems. In the process of experimental teaching, teachers should focus not only on mastering conclusions but also on learning and understanding the process. They should truly make students the masters of the classroom, encouraging them to actively participate in the entire development and occurrence of knowledge, thereby further fostering students' innovative awareness and enhancing their practical skills and abilities. In the future, we will continuously improve teaching methods and innovative approaches based on student feedback. We will strive for ongoing improvements according to students' acceptance levels and work to optimize and innovate other practical courses simultaneously, so as to provide more high-quality and application-oriented talents for the industry.

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References

[1] Sun G, Fang Y. Guo X M, Wang Y Q, et al. On the application-oriented talent training model of oversea universities and its revelation [J]. Journal of Jilin engineering normal university, 2016, 32(1): 1-3.

[2] Sheng Y. Education applied research based on applied personnel training[J].Journal of educational institute of jilin, 2019, 35(1): 122-125.

[3] Zhou M, Wang R, Zhao X H. Exploration on reform of experiment teaching in fundamentals of materials science[J]. Guangzhou chemical industry, 2023, 51(3): 277-279.

[4] Li H L, Zhang J B, Liao C Z. Exploration and practice of mixed teaching mode in the course of basic experiment of materials science[J].The guide of science & education,2021, 5: 116-117.

[5] Li M C. Exploration on the teaching reform of basic experimental in materials science [J].University ,2023, 11(593): 157-160.

[6] Li Y Y, Ye F, Liao C Z, Zhang J B. Teaching reformation and practice of fundamentals of materials science experiment based on micro-lecture and rain classroom[J].Guangdong chemical industry ,2023, 47(430): 185-186.

[7] Yang J H, Fan Q, Yin S Q. The application of diamond software in teaching"an introduction to material science" [J]. Journal of leshan normal university, 2015, 30(04): 108-110.

[8] Liang K Z, Jiang D M. Reform and practice in polymer chemistry experiments of application colleges[J].Shandong chemical industry ,2020, 49(20): 207-208.

[9] Gao R, Pan X Y, Hua L, et al. Exploration on the teaching reform of the material science foundation under the training mode of applied talents[J].Education teaching forum,2019, 20: 72-73.