Scientific Research Project Curriculum: A Clever Teaching Method of "Scientific Research Nurturing Teaching"

Hui Liu1, *, Qiuhao Yu1, Zhoumeng Cui1, and Deng-Guang Yu1, 2
1School of Materials and Chemistry, University of Shanghai for Science and Technology, Shanghai 200093, China.
2Shanghai Engineering Technology Research Center for High-Performance Medical Device Materials, Shanghai 200093, China.

Abstract. Higher education shoulders the task of cultivating high-level professionals with innovative spirit and practical ability. Undergraduate education plays a vital role as the beginning of higher education. However, the existing undergraduate teaching content is relatively outdated and the teaching mode is simple, making it difficult to stimulate students' learning interest and improve their innovative practical ability. The scientific research project curriculum is rich in content and diverse in teaching forms, which can not only expand the teaching mode but also enrich and supplement professional knowledge. In this work, the teaching method of scientific research project curriculum is investigated in the investigated discipline - Material Science and Engineering. It is demonstrated that the introduction of scientific research project curriculum into undergraduate education or graduate education can help students improve their independent learning enthusiasm, professional practical skills, and innovative thinking abilities in the process of solving practical scientific research problems. Particularly, a project course about electrospun nanofibers is demonstrated to be a facile approach for achieving a comprehensive practice training for students. In a word scientific research project curriculum has proven to be a good teaching method for achieving "scientific research nurturing teaching".

1. Introduction

As the beginning and foundation of higher education, undergraduate education plays a vital role in the cultivation of high-end professionals. [1,2] Higher Education Law of China clearly stipulates that "the task of higher education is to train senior professionals with innovative spirit and practical ability". [3] Colleges and universities, as the carrier of higher education, shoulder the bounden responsibilities. [4,5] Usually, practical courses and theoretical courses coexist in the undergraduate education of materials science and engineering, and practical teaching bears the important mission of cultivating students' practical innovation ability. [6,7] However, the content of most traditional practical teaching course consists of many step-by-step verification experiments that are outdated. Moreover, there are few organic connections among the experiments, which seriously restricts the improvement of students' abilities to discover problems, analyze problems, solve problems comprehensively and innovation capacities. Meanwhile, the current undergraduate education pays more attention to the teaching of subject basic knowledge, while the training of scientific research ability is insufficient, limiting the students to pursue further studies.

Researchers need to integrate and apply basic knowledge flexibly during the process of scientific research, thus deepening the understanding of existing knowledge. Moreover, the scientific research results can complement and improve the existing basic knowledge in turn, so as to realize the updating of professional knowledge. Additionally, most of the teachers' scientific research projects come from production practice or cutting-edge research of the field, which is full of teachers' in-depth thinking on professional issues. Introducing scientific research projects into undergraduate education is an ideal strategy to help students improve their independent learning enthusiasm, professional practical skills, and innovative thinking abilities in the process of solving practical scientific research problems. [12,13] For graduate students, participating in teachers' project research in advance lays a good foundation for completing their own Master project. Scientific research and teaching are two wings that are indispensable to promote the development of colleges and universities. Teaching, as the fundamental task of a university, is the basic way to promote scientific research and scientific research is an important mean to nurture teaching (Fig. 1).
2. Implementation key points of scientific research project curriculum

Scientific research project curriculum refers to a new type of scientific research academic or industrial cutting-edge curriculum that teachers combine scientific research with undergraduate teaching organically and transform the research content of scientific research projects into teaching resources for undergraduate courses. In such curriculum, students can promote independent learning of relevant courses through project practice, thus improving their scientific research literacy and innovation ability. Similar to other teaching courses, the persistence of strengthening moral education and cultivating people is still the fundamental requirement of this curriculum. Therefore, it is necessary to strictly control the teaching quality of the scientific research projects curriculum. Here, we summarized the following four major points according to the implementation of the curriculum: the combination of theory and practice, detailed practice plan, clarified course goals and optimized course evaluation system (Fig. 2).

2.1. Combination of theory and practice

The scientific research project curriculum is not a simple experimental operation course. The study of theoretical knowledge can not be ignored while paying attention to the cultivation of students' practical ability and innovative thinking. The research background, research significance, scientific problems and even research programs of the project involve some professional basic and cutting-edge theoretical knowledge. Leading students to dig and interpret the relevant theoretical knowledge is contribute to deepen students' understanding of basic theories and learn cutting-edge major knowledge, which can greatly enhance students' learning interest and application ability of theoretical knowledge. In addition, the acquisition and understanding of theoretical knowledge is also the basis and precondition of practice, providing theoretical guarantee for the successful completion of subsequent practical operations.

2.2. Detailed practice plan

The scientific research project curriculum is mostly carried out based on provincial or national level scientific research projects chaired by teachers. The content of a project is often an interlinked whole. Thus, it is very important to split the content reasonably and develop detailed implementation plans of each part according to the number of students and the teaching progress. Teachers can first group the students on the basis of the number selected, and then split the project research content into different modules according to the group of students and the teaching plan. Each group of students is responsible for a small module and a core problem was proposed by the teacher for everyone to think about and solve in each module. Meanwhile, teachers should also provide some referable practice schemes or research methods in advance to guide and inspire students to conduct independent exploration and cultivate students' abilities of discovering, analyzing and solving problems, enabling students to master the methods and skills of scientific research and innovation.

2.3. Clarified course goals

Different from traditional courses, scientific research project curriculum pays more attention to the cultivation of students' independent learning ability, innovative practice ability and scientific research accomplishment. Therefore, scientific research project curriculum should have more clarified goals that are different from traditional courses. During the early stage of the course, we should focus on the theoretical teaching of experimental operation principles, methods and safety related to the project content, and teach students the skills of literature retrieval and reading as well as. The goal, in this stage, is to guide students to master the basic knowledge of the subject, improve the ability of independent learning, track the frontier of the development of the subject, and broaden the academic horizon. In the middle period of the course, project experiments are the main focus. According to the advancement of experiments, students are guided to find and solve problems to learn scientific thinking from this process. At this stage, the goal is to improve students' innovative practice ability and cultivate students' scientific research thinking. At the end of the course, teachers should instruct students to analyze and discuss experimental data, thus making charts and summarizing results. At this stage, the goal is to cultivate students' research awareness, summary and scientific language writing abilities.
2.4. Optimized course evaluation system

The form of scientific research project curriculum is more flexible, and the content is more colorful. Therefore, the traditional single finality evaluation model of "one exam determines the overall situation" is no longer applicable, while the whole process evaluation model combining process and finality is more reasonable. Moreover, more attention should be paid to the assessment and evaluation of students' practical ability and innovative ability. Therefore, it is suggested that the abilities of information retrieval, key experimental operation spotting problem and scheme optimization should be taken as the key evaluation indicators for the process assessment. The final assessment can be evaluated by the results of project summary, paper submission, patent application and so on. In short, the academic evaluation of scientific research project curriculum should be evaluated according to the project nature and the progress by the teacher who chairs the project, and should not be generalized.

3. An example of research project courses on electrospinning nanofibers

Electrospinning can be regarded as an extension of traditional electrospaying technology, which allows polymer solution with a certain viscosity to be ejected as continuous jets at a critical voltage and form polymer fibers of micro and nano scales (Figure 3a). [14,15] Both the solution properties, process parameters and environmental conditions have great effect on the final fiber structures and properties. [16-18] Studying the effects of these factors involves physics, chemistry, mathematics and other multidisciplinary knowledge, which is a practical example and good teaching materials for undergraduate or graduate students’ education. Meanwhile, electrospinning itself is an engineering issue that need to be optimized for successful fabrication of nano products. Moreover, with the development of electrospinning technique, spinning equipment and fiber structures are becoming more and more colorful. For example, co-electrospinning equipped with coaxial needle, offset coaxial needle, parallel coaxial needle or tri-layer coaxial needles are developed and nanofibers with columniform structure, beaded structure, spider-web-like structure and so on are prepared (Figure 3). The whole process of choosing the suitable raw materials, solvents, process parameters, equipment to fabricate nanofibers with structures that meet our requirements can be used to cultivate students' innovative spirit. And during the electrospinning, there are many experimental techniques should be mastered, and even some of the equipment components are made by ourselves, such as spinning needles. These experiences help to develop students' practical abilities. Therefore, such research project course of electrospinning nanofibers not only fed back on the most fundamental educations on the basic courses such as mathematics, physics, chemistry and engineering, but plays an important role in cultivating innovation and practical abilities of undergraduate and graduate students.

Fig. 3. An example of electrospinning process, technique and fiber structures in research project courses for education.

4. The teaching results of scientific research project curriculum

The cutting-edge, interesting and flexible nature of the scientific research program curriculum makes it more popular among undergraduates. Therefore, the start of scientific research project curriculum is easier to achieve more excellent teaching results. Now it can be summarized as the following three points (Fig. 4):

4.1. Realizing a close integration of theory and practice

The scientific research project involves a large number of professional basic knowledge and cutting-edge theories as well as teachers' condensed thinking on professional issues. Students need to have a solid reserve of professional theoretical knowledge and excellent learning ability in understanding the research background, significance and content of the project. Through this training process, students have a more comprehensive and thorough understanding of professional knowledge. At the same time, during the implementation of the project, students will continue to encounter many new problems that need to solve by consulting the relevant new theoretical knowledge. This process not only deepens the students' understanding of theoretical knowledge, but also realizes the application
of theoretical knowledge and promotes the close integration of theory and practice.

4.2. Enhancement of students’ initiative in independent learning

The implementation of the scientific research project curriculum is not simply to inculcate boring and established basic knowledge, but to explore the process of using theoretical knowledge to solve practical problems. This process is full of uncertainty and flexibility that requires students to continuously learn more theoretical knowledge and experimental skills independently, which is conducive to improving students' information acquisition and learning abilities, and deepening their understanding and application of knowledge. In addition, most of the teachers' projects come from industrial practice or close to life, which can stimulate students' interest and encourage them to take the initiative to conduct in-depth exploration of experiments. The result of practice showed that the implementation of the scientific research project curriculum not only deepens the depth and breadth of the teaching content, but also greatly improves the enthusiasm of students in independent learning.

4.3. Improvement of students' practical innovation abilities

In the implementation of scientific research project curriculum, students need to use advanced experimental or technical means to solve the practical problems, which puts forward higher requirements for students' practical ability. More importantly, this mode can effectively avoid the passive attitude of students arising from not seeing the practical application in traditional experiment classes. At the same time, unexpected results will constantly appear in the process of operating, requiring students to constantly think about new or better solutions, which is contribute to the improvement of students' innovation ability. Practice has proved that through the training of scientific research project curriculum, students become more skilled in practical operation and awareness of innovation is enhanced.

5. Conclusion

The set up of scientific research project curriculum is a measure to achieve multiple goals. On the one hand, teachers can get some time for scientific research while completing the teaching tasks. At the same time, they can think more deeply and review their own project content as teaching students, laying the foundation for future project application. On the other hand, students can get access to the most cutting-edge theoretical knowledge and practical cases by participating in the scientific research project courses, so as to enhance their interest and enthusiasm in learning. Moreover, they can learn skills of information retrieval, literature reading, experimental operation, data analysis and others that can help cultivate students' practical innovation and scientific research abilities. The scientific research project curriculum is not only an important carrier of moral education and student cultivation but also an important link that cannot be ignored in the process of “Three-All Education”. Integrating scientific research projects into the undergraduate teaching process expands both the traditional teaching mode and the teaching content, making it easier to achieve the goal of cultivating innovative talents and effectively realize a win-win result of "teaching promotes scientific research and scientific research nurtures teaching".

Acknowledgment

This work was supported by the Natural Science Foundation of China (No. 52203062), Shanghai university young teacher training funding program, the USST student innovation project (USST-2023) and the USST graduate course ideological and political project.

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