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Exploration on Teaching Reform of Genetic Engineering

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***Abstract*—Exploring the new teaching model of *Genetic Engineering* can enhance the teaching quality and ultimately cultivate innovative "Emerging Engineering" talents for biopharmacy major. Through introducing frontier scientific research progress to optimize course contents based on classic textbook, using modern multimedia tools and heuristic to enrich teaching methods, expanding explorative and comprehensive experiments to improve experimental teaching, and carrying out student's scientific research projects and enterprise internship, it promotes learning for practice. Through the in-depth cooperation between classroom teaching and extracurricular practice, the *genetic engineering* curriculum has been transformed from "teaching-based" into "learning-oriented" and eventually "application-oriented", and the teaching efficiency has been drastically improved. It has greatly arouse students' learning interest and initiative, cultivated their logical thinking ability, professional skill and creativity on scientific research. Most importantly, it transformed theoretical learning to practical application, which benefits to the cultivation of the "Emerging Engineering" talents.**

Keywords—Genetic Engineering; Biopharmacy; Emerging Engineering; Teaching Reform; Teaching Practice

I. INTRODUCTION

"Emerging Engineering" is the reform direction proposed for engineering education based on economic demands and industrial upgrading in China. The goal is to cultivate highly qualified talents with strong scientific foundation, innovative engineering ability and international competitiveness [1-2]. The biopharmacy major is one of the nine "Emerging Engineering" majors proposed by the Ministry of Education of China. In order to cultivate talents that can meet the requirements of the burgeoning bio-industry, the traditional engineering education mode is in urgent need of reform, which sets higher demands upon the teaching quality, knowledge and ability of college teachers.

Genetic engineering is an essential course of biopharmacy major and a leading course guiding professional core such as microbiology and biopharmaceutical technology. So it plays an important role in biopharmacy curriculum system [3]. Like other engineering courses, *genetic engineering* is highly operational and practical, and its technology principles are detailed and complicated. Therefore, in classroom teaching, teachers are easily to lay particular stress on the interpretation of the principles of engineering technology, whereas neglect the introduction of technical operations and practices in details. As a consequence, theory is separated from application, and what is learnt cannot be applied into usage. That deviates from the original intention of teaching. In order to improve the teaching quality of *genetic engineering* course and meet the teaching objective of cultivating the "Emerging Engineering" talents in this major, the authors conduct a preliminary study on teaching reform in terms of course contents, teaching methods, experiments teaching and practices of scientific research projects.

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II. OPTIMIZING TEACHING CONTENT AND HIGHLIGHTING COURSE FEATURE

Genetic engineering is a highly technical course, which is based on genetic materials and emphasizes the design and operation of genetic materials according to the approach of engineering [4]. In recent years, with the development of synthetic biotechnology, new biotechnological research achievements have emerged rapidly, and science and technology has been updated constantly. However, the current content of *genetic engineering* textbooks has not yet been line with the scientific research progress comprehensively. The content just embraces the classic technical route of DNA molecular cloning, including the main technology principles of *genetic engineering*, namely, enzymatic basis, vectors, gene amplification, in vitro recombination and recombinants screening. Therefore, in order to cultivate students that can keep pace with the technology development, the lecture content strives to reflect the advanced research progress based on the systematic knowledge of *genetic engineering*. Some excellent frontier technologies, such as DNA assembly and Crisper-Cas9, are carefully selected and appropriately introduced into classroom, so that students can grasp the latest technologies besides textbook.

In addition, *genetic engineering* is a multidisciplinary course. The arrangement of teaching content should also focus on the connection of interrelated knowledge with other courses, so that students can better understand the knowledge points and the integration of interrelated knowledge. Meanwhile, during the boring course of theoretical teaching, teachers should add some interesting life cases related to teaching content to stimulate students' learning interest. For instance, the Nobel

Prize winner Tu Youyou, a Chinese scientist, discovered the antimalarial drug artemisinin, and then the American scientist Jay Kreasling made the best of genetic engineering technology and finally realized the commercial production of artemisinin for charity use [5]. Moreover, teachers should pick some attractive food pictures such as cherry tomatoes, purple potatoes and colored rice, to question students whether these food belong to the genetically modified foods or not, and then ask them to have an open discussion on genetically modified foods. Through linking the teaching content with actual life, the classroom has become quite active and students' enthusiasm for learning has been greatly enhanced. Benefiting from these, it is easier for students to absorb knowledge in a pleasant learning atmosphere.

III. Enriching Teaching Methods and Improving Learning Efficiency

The objective of *genetic engineering* is to enable students to master genetic engineering techniques and their principles, and to flexibly use genetic engineering techniques to engineer organisms and realize bio-manufacturing. Traditional infusion teaching methods advocate the blind output of curriculum knowledge, but the complicated and cumbersome technology theories often make many students overwhelmed and dizzy, and eventually lost their interest in learning due to the low efficiency. In view of this, enriching teaching methods is ought to be another key direction of teaching reform of *genetic engineering*. Diversified teaching methods should be introduced into the classroom in order to motivate students' learning enthusiasm and improve learning efficiency.

First of all, modern multimedia teaching tools should be utilized to concretize the abstract concepts in courseware. For instance, teachers can use vivid pictures to replace the obscure text descriptions in courseware; teachers can use intuitive technique flow charts to replace the plain technical protocols in textbook. On this basis, visualization tools (flash, video, etc.) would be introduced to make complicated engineering techniques intuitively demonstrated. Take the teaching of DNA electrophoresis as an example. An auxiliary how-to video can help students master this technique thoroughly. Besides, heuristic teaching methods is ought to be used in classroom teaching in order to train the ability of initiative to learning, logical thinking and innovation. For example, after interpreting the knowledge of DNA polymerase, T5 exonuclease and Taq ligase, group discussion would be carried out to let students think about how to use these three enzymes to achieve Gibson assembly [6]. This kind of heuristic teaching method can greatly improve classroom participation, arouse learning enthusiasm, and cultivate students' creativity and logical thinking ability. Finally, after class, the sharing of useful curriculum resources and the latest achievements of genetic engineering through the internet should also be supplemented in addition to classroom teaching. That would facilitate students to comprehensively grasp of the curriculum knowledge system and to further expand professional knowledge. In general, the application of diversified teaching methods is conducive to the transformation of *genetic engineering* curriculum from "teaching-based" into "learning-oriented", which ultimately contributes to the improvement of teaching efficiency.

IV. Optimizing Experimental Teaching and Cultivating Research Interest

Genetic engineering is a course that closely combines theory with practice, and it belongs to the upstream technology in the field of biopharmacy. Learning *genetic engineering* will be helpful in a better understanding of downstream biopharmacy technology. Theoretical teaching emphasizes the mastery of technical principles, but the technical practice is of equally importance. As an extension of the theoretical curriculum, the experimental curriculum is set independently, aiming to consolidate the theoretical knowledge and apply it to the practice of genetic engineering.

In undergraduate education of engineering majors, experimental teaching plays a critical role in associating the theory with practice, and its objective is to train students' professional experimental skills and cultivate research interests. In traditional experimental courses, the most majority of experiments are replication experiments. Replication experiments are usually designed in detail to verify that a known result is correct, so that students are passive in learning [7]. In order to give full play to students' subjective initiative and creativity, the experimental course of *genetic engineering* is designed to add both comprehensive experiments and exploratory experiments to the original replication experiments, which are just composed of classic operations like restriction enzyme digestion, DNA ligation, *Escherichia coli* transformation and recombinants screening. For example, teachers can set up a comprehensive experiment in which gene expression cassette of green fluorescent protein should be assembled by PCR and then be transformed into *E. coli* for highly efficient expression. Through such comprehensive experiments, students' mastery of molecular cloning and gene expression skills could be examined, and students are able to review and connect various knowledge learned in theoretical course for accomplishment of one technical route.

In the short-term practical courses, an open-ended exploratory experiment should be designed in combination with major characteristics. In this experiment, students are allowed to propose a feasible solution for highly efficient expression of cellulase in *E. coli* and then apply this recombinant *E. coli* to realize waste paper degradation. During the courses, students can be grouped by an average of five people. Each group should design their own experiments, propose reasonable scheme and then collaborate to complete the experiment under the guidance of teacher. At the end of the course, each group should give a report on their experimental methods and obtained results in the format of PPT, and every result will be carefully analyzed and discussed together. Through such exploratory experiment, students' scientific research interests are fully stimulated and their logical thinking and hands-on skills are fully trained. Through the progressive teaching from replication experiments toward comprehensive experiments and exploratory experiments, students are able to thoroughly master the unit operation and integrated technique modules of genetic engineering and are trained to possess the abilities to discover, analyze and solve problems by applying

genetic engineering theory and technology. In general, the optimization of experimental teaching is conducive to the transformation of *genetic engineering* curriculum from "teaching-based" into "learning-oriented", reflecting the improved quality of *genetic engineering* experimental teaching and teaching efficiency.

V. Promoting Teaching While Researching and Learning for Practice

Teaching is the foundation of scientific research, and scientific research can promote reflection on teaching. They complement each other and integrate themselves. It is especially true for engineering majors. The main characteristic of engineering teaching is of strong practicability. Course study is mainly used to solve practical problems, and the knowledge system validated by practice can in turn promote teaching [8]. Teaching and practice build on each other and promote each other. As an "Emerging Engineering", the biopharmacy major focuses on the combination of production, education and research. Therefore, in the practice of *genetic engineering* curriculum reform, it is necessary to not only strengthen classroom teaching, but also let students go out of the classroom to participate in actual scientific research and production process.

Inside the school, teachers are practitioners in the field of biopharmacy. By guiding undergraduates to participate in teachers' research projects, students have a chance to approach scientific research. During the research practice, students can better understand the knowledge system and the application of *genetic engineering* in pharmaceutical field, and realize that genetic engineering is not to discover, but to create. Specifically, teacher's research project can be decomposed and assigned to relevant 4-6 students for application of the "Zhejiang University Students Science and Technology Innovation Activity Plan" project or the "National College Student Innovation Training Program" project. The research process of students' project is student-centered, and the teacher just acts as a consultant, so that students' scientific creativity could be stimulated as much as possible. Under the guidance of teachers, the student team is able to complete the whole research process independently from project application to project completion. At the end of the project, each team needs to submit one detailed research report and make an oral defense on their achieved research progress for competition, and eventually, top five teams will be selected and awarded with honor. Consequently, students' scientific research abilities and professional skills in biopharmaceutical field will be remarkably improved through such competition.

Outside the school, students are arranged to enter into enterprise to access the industrialized production lines of genetic engineering pharmacy. Internship in enterprise is an effective way for students to gain a deep understanding of professional knowledge and to get in touch with the industry dynamics. It enables students to broaden their horizons and understand the needs of enterprises. Presently, our university has established good relationships with Zhejiang Haizheng Pharmaceutical Co., Ltd.. Thus, for production practice, undergraduates are arranged to go out of the campus and join the Haizheng to learn the research and development process of actinomycin D. Throughout the internship, experienced technicians will be accompanied to explain key techniques such as the strain construction and mutation breeding. The firsthand experience of *genetic engineering* will help students to establish a professional knowledge system to truly apply with what they've learned. Through connecting classroom teaching with actual scientific research practice, *genetic engineering* curriculum is transformed from "learning-oriented" into "application-oriented", and the cultivation quality of "Emerging Engineering" talents for biopharmacy major has been greatly improved.

VI. Conclusion

Under the background of "Emerging Engineering", the biopharmacy major has paid more and more attention to the cultivation of applied and innovative talents, and the undergraduate teaching reform is imperative. Based on some teaching experiences accumulated in the process of teaching practice, this paper makes a preliminary exploration on the teaching reform of *genetic engineering* from four aspects, namely, teaching content, teaching methods, experiments teaching and practices of scientific research projects. Cutting-edge research achievements should be appropriately selected into course content to increase students' learning interest,; diverse teaching methods should be used to motivate learning enthusiasm and improve learning efficiency; comprehensive and exploratory experiments should be stepwise carried out to cultivate students' logical thinking and hands-on abilities; and scientific research projects and enterprise internships are ought to be properly arranged to promote teaching and practice integrally. Through the teaching reform above, the curriculum is transformed from "teaching-based" into "learning-oriented" and eventually "application-oriented", which ultimately improves the quality of "Emerging Engineering" talents training.

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