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An Experimental Module in the Teaching of Genetics, with a Special Reference to Reform and Innovation in Genetics Experiments

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Abstract

Genetics is a major course in Life Sciences, and also a basic course in other disciplines or specialties, such as Agricultural Sciences, Medical Sciences and etc. Genetic experiments are not only the important content of the undergraduate teaching in Life Science but also the most common and efficient teaching approach in Life Science. Based on an introduction to reform and innovation of genetics experiment instruction, this article aims at discussing how to classify experimental modules and teaching practices. In our experimental test, the whole experiments consist of three modules: general experiments, integrated experiments, and research-based experiments. The research-based experiment is given as an instance. We herein figure out the instruction of experiment contents and guidance of learning methods, corresponding to various requirements in different teaching stage. In our opinion, post-graduates can act as teaching-assistants, which will facilitate undergraduates to participate in genetic experiments, improve their ability to operate by hand, and foster their innovative consciousness and scientific-thinking ability.

Key words: Genetics Experiment; Teaching System; Modules; Teaching Strategy

1 INTRODUCTION

Changes in our global world have shifted the skill demands from acquisition of structured knowledge to mastery of skills, which had a profound impact on education and teaching in global colleges and universities [1-3]. In the late 1990s, many new curricular proposals and innovative teaching strategies were developed to promote substantial change of university education in the coming years. In China, the entire curriculum system in the field of Life Science has been changed with the development of biotechnology (especially molecular biology) education in the past decade [4]. In fact, curricular reform of life science in Chinese university began in the early 2000s, which was characterized by large-scale curricular phases and instructional practices for undergraduates. Genetics is a rapid development subject, which focuses on practice, and is also a multidisciplinary cross-integration of the subject with rich scientific knowledge and techniques [5-7]. It is an important required course for the undergraduate students who major in Life Science, Biotechnology, Medical and Medicinal Science [8], Agronomy and Forestry [9], and etc. With the development of molecular biology, the contents of genetics have been greatly enriched in breadth and depth. The reform of the curriculum is mainly reflected in several aspects: optimizing the content of the curriculum, improving the teaching methods, strengthening the experimental teaching and so on [10]. Thus, genetics experiments as important components of the genetics course were attracted a lot of attention [11-14]. However, traditional experimental teaching focuses on the experimental operation of students. During the experiment, most of the work was prepared by the technician before class, which includes material collection and processing, preparation of reagents, debugging of instruments, selection of experimental conditions, etc. All students need to operate only according to the experimental instruction [14]. Thus, genetics experimental teaching should keep up with the discipline development. The reform of experimental teaching mainly focuses on teaching content, teaching mode, assessment method, etc. [15].

In an overview of previous literature, there was a larger collection of papers on genetics and its experimental teaching, and a number of reviews had appeared on the experimental teaching contents and methods [6, 16]. With the reform of the global life sciences curriculum, in "Undergraduate Student Research Training Program" of Fudan University in Life Sciences, the purpose of reform and innovation genetics experiment is also to culture the talent of the students in scientific research [17]. In numerous studies, experimental teaching of "modular" and "open" has become the focus of reform [18,19]. Genetics is a fundamental course in medicine, pharmacy and life sciences at Fudan University, the goals of course reform are to cultivate the talent of students like genetic analysis of the background and to enable the students to utilize a variety of analytical tools. The students need to improve the analysis, understanding and problem-solving abilities. Under the guidance of a professional development program, we have developed an experimental progressive step by step-teaching-system, in which experimental items are arranged from "basic module", "integrated module" to "research-based module" gradually [20]. Through more than ten years of teaching experiments, the teaching reform of the curriculum has achieved obvious benefits in talent training. In this paper, we introduced our reform ideas and primary practices in the experimental teaching, which may serve as a useful reference for science teaching reform all over the world.

2 METHODOLOGY

2.1 Experimental Course Design

The design of genetic experimental course depends on the development of the student's skills. In previous studies, we divided the practice and training skills into three different stages: skill learning, skill experiencing, and skill developing [17]. So the whole experimental system on genetics was divided into three modules, and each module might contain one or more experimental items. In general, the item would be modified each year, but the module was relatively invariant. In Fudan University, the experimental course system of genetics was divided into three modules as follows.

2.2 General Experiments

Main task of the basic experiments is to enable students to learn to use laboratory equipment and to master standardized methods and the basic techniques of genetic experiments. Those include (1) the basic operation of washing, weighing, reagent preparation; (2) the basic skills, such as centrifugation, colorimetric, microscopic observation and electrophoresis; (3) basic culture skills: germ culture, cell culture, tissue culture and so on. In addition, the use and maintenance of some precision instruments are very important, such as balance, pH meter, the centrifuge, UV and visible spectrophotometer, semi-automatic biochemical analyser, microscope, electrophoresis system, PCR, bio-imaging systems, clean bench, incubator, vacuum freeze drier, etc. In this portion, genetic analysis of biological trait patterns of model organism, such as genetic analysis of patterns of drosophila traits, genetic analysis of chromosome and etc., is the most basic skills of genetic experiments.

2.3 Integrated Experiments

Integrated experiments refer to those including comprehensive knowledge of several subjects. Through these experimental training, the students could enrich knowledge, design a new experiment and obtain an integrated training on experimental skills and methods. Its main characteristics are an integration of all the experimental skills, such as experimental analysis, operational ability, data-processing capability, and the ability to access multi-disciplinary knowledge and problem-solving ability. The students have to learn to use different methods and techniques to complete the same content of the scheduled experiments. Comprehensive experimentation includes the genetic analysis of gene function, which involves three kinds of experiments: the mutagenesis caused by insertions transposon, the limitations of bacterial transduction, and the chemical synthesis of double-stranded RNA to interfere with the expression of GFP (green fluorescent protein), etc.

2.4 Research-based Experiments

Research-based (or design-oriented) experiment is a kind of exploratory experiment combined with curriculum teaching or some other trial. The experimental process possesses a typical characteristic, which is "research-based"

through the whole experimental process. The entire experiment must be individually operated by the students, so that they have to independently make designs, operations and innovations without the help of any tutor. The main content of the research-based experiments includes genetic analysis of biological evolution, genetic analysis of mutations, and genetic analysis of hereditary relationship. The genetic experiments are one of the required courses of many undergraduate specialties, such as Life Sciences, Biotechnology, Medicine and Pharmacy. In the new experimental teaching system, the entire experiments will be divided into three modules, while the content of each module (item of experiments) will change each year. Moreover, items of experiments will be adjusted in accordance with the general interest and vocational career characteristics of the students. In this way, teachers can introduce advanced technologies of the research projects into the undergraduate teaching experiment in order to enhance the technical content of the experiments.

3 EXPERIMENTAL CONTENTS SELECTED

Here the module of analysis of human relationships in the research-based experiment was selected for statistical analysis of the effect. Experiment content is to select a pilot project for the cultivation and training of students' theoretical level, experimental skills, and experimental methods. The contents of the module of analysis of human relationships of research-based experiments are available in Table 1.

TABLE 1 EXPERIMRNTS AND CONTENTS IN THE MODULE OF ANALYSIS OF HUMAN RELATIONSHIPS

Time	Experiment name	Content of skill	Item of skill
Week 1	Extraction of genomic DNA from human fresh salivary gland cell	Collection of human fresh salivary gland Extraction of genomic DNA	Extraction, isolation and determination technique of nucleic acid.
Week 2	Expand the special segment of human mtDNA by polymerase chain reaction	Primers design: including human mtDNA special segment and variable numbers of tandem repeat *DIS80* Optimization of PCR reaction volume and condition	Techniques of design primers; Usage of PCR instrument.
Week 3	Obtainment of special segment of human mtDNA from agarose gels	Preparation of agarose gel Preparation of DNA sample Agarose gel electrophoresis Extraction of DNA fragments from agarose gels	Technique of agarose gel electrophoresis Collection of DNA fragments
Week 4	Ligation, transformation and selection of positive transformants	Optimization of ligation volume and condition Preparation of competent cell Transformation of plasmid for *E. coli* Selection of positive transformants	Transformation techniques; Selection of positive transformants
Week 5	The rapid propagation of positive transformants and extraction of plasmid	Obtainment of positive clones The rapid propagation of positive clones Extraction of plasmid	Extraction of plasmid
Week 6	Identification of positive plasmids by restriction enzyme	Selection of protocol for DNA restriction enzyme digestion Optimization of double restriction enzyme digestion Observation and analysis of enzyme digestion results	Selection of DNA restriction enzyme digestion; Identification of positive plasmids.
Week 7	After identified by restriction enzyme digestion, sequence reactions	Learning of nucleic acid analysis software Sequence analysis	How to analysis of sequence

3.1 Organization and Implementation

According to a regular pattern of skill learning and the tradition of comprehensive universities, supervision of the teachers must go through three different stages in the course of experimental teaching. The three different stages have different guidance of each operation at different levels, which include each experiment, each period and the total experimental design. In these stages, the former is the foundation and the latter is the inevitable results. Different schools (or colleges), different students and different experiments need different time on each stage, so that there exists some difference in different stages of training. For example, there are a total of seven experiments in the module of the test in the Fudan University and this will take seven weeks to complete, as showed in Figure 1.

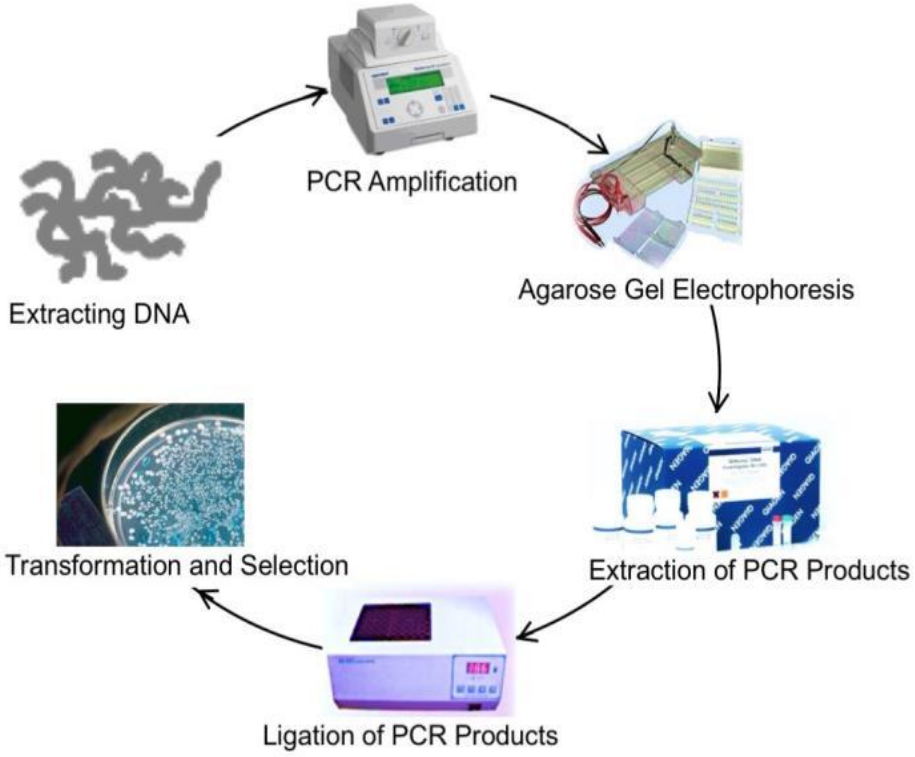

FIG. 1 EXPERIMENTAL PROCESS OF ANALYSIS OF HUMAN RELATIONSHIPS AT FUDAN UNIVERSITY

Guidance of each operation means the guide of each experimental detail (or step) given by a teacher or a graduate student who acts as teaching assistant, usually an action as a unit. The guidance of each section of operation refers to demonstrations and explanations of a project (or a certain period of an experiment), usually in units of the project. And the guidance of experimental design is to make an overall arrangement, with which students can solve the whole problem by learning the design methods and application technologies, usually the problem to be solved as a unit. Experimental guidance includes three aspects of content: preparation, operation process and the experimental report. To check the implementation of the experiment, the students just have to complete reports of these three aspects, and the post-graduate assistants or the teachers will provide assistance and guidance. The contents of those reports are presented as follows.

Firstly, the preparation report is a task ahead of the experiments, and the students just have to read the instructions and recommended papers carefully, review the related knowledge and theories, and figure out the purpose of the task. The key thing is to understand the principle of the experiment thoroughly, and make sure the experimental specific contents and the problems to be solved, e.g., what phenomenon is to be observed? What data is to be measured? What method and steps will be adopted?

Secondly, the process report is another type of task after each experiment is completed by students. They must

carefully check the record of the projects, data, and units. And does it match the expected experimental results? If the experiment fails, then they should seriously look for the causes.

Thirdly, it is the last report. An integrated true result of the experiment is expected to be reported concisely and firmly. In a word, fluent text, concise and correct writing, clear chart, rational analysis and the correct conclusion constitute a conclusive report. Of course, in the different periods of developing skills, the content and methods of the guidance change a lot. At the stage of the experimental design, teachers should take more attention to the other aspects of skill developing for the emphasis of training transfers gradually. Therefore, the guidance of teachers will have undergone substantial changes. It is such a valuable process that students could improve and complete themselves profoundly under the help of the teachers' guide. The old form of report would be replaced by a design report, implementation report and analysis report.

In order to facilitate students to self-study, the lab increases the openness of it and also provides a network experiment environment, in which students may easily obtain the required experimental resources. For instance, experimental material and other resources can be downloaded by the FTP (file transfer protocol).

3.2 Evaluation

In the assessment, the evaluation of the learning process of the student is important that directly affect the initiative and positivity of students. The final grade of a student consists of the combine regular grades (accounting for 70% of the total score) and final exam grades (accounting for 30% of the total score). The following guidelines apply only to regular grades, including some specific elements such as the rate of attendance, question-asking in the classroom, experimental approach, experimental operation, experimental results, experiment reports and the ability of problem-solving and innovative design in the experiments. Evaluations of regular grades are given by the graduate teaching-assistants and teachers in different experiments. Primarily, final examination focused on the mastery of basic experimental skills, experimental theory and the ability of analysis on experimental problems. Comprehensive Strength of students will need to be fully evaluated.

There is 153 student's participation in the test of experimental instructions. After the experiment, we have made an investigation of the effect of the reform of genetics experiments by the questionnaires, seminars or individual conversations, etc. The focus appears on two aspects: students' attitude to the reform of genetic experiments, and experimental items the students like.

4 RESULTS

Survey results showed that in the questionnaire of the 153 students, 122 students (79.74%) thought that the effect was good or very good. They believed that integrated experiment in the fingerprinting analysis and in the analysis of the evolution of mtDNA can improve the students' interests; for research-based experiment to be open or not (including instructor-led method), 135 persons (85.62%) showed an affirmative attitude, 17 persons (11.11%) opposed; 5 (3.27%) said that it does not matter. Other results showed that the most preferred genetic experiments with the greatest gain are RNAi experiments, which include items of the inhibition of EGFP expression by RNA interference, the analysis of the evolution of mtDNA and the ABO blood type experiments (the model of ABO blood type experiment by PCR and restriction enzyme digestion). In their view, these experiments are related to life and people-oriented. In addition, the experimental set-up reflects the humanization characteristics.

5 DISCUSSION

New experimental teaching system, which has a clear request of cultivating professionals, fully embodies an inevitable link and interdependent relationship between classroom instruction and the experimental teaching, and it is suitable for many courses. It pays more attention to grasp the basic rules of the teaching experiment. Experimental arrangement reflects a guiding ideology that is from simple to complex and from single point to multipoint. The experimental teaching system improves the basic knowledge and basic skills in the original experiment and set up some integrated design experimental projects which are independent from other course, e.g., design of pilot projects, so that the experimental content is balanced and improved gradually. Experimental teaching and modular

development greatly increased the effectiveness of experimental teaching and students' enthusiasm for participation. However, in the process of reform and innovation in Genetics experiment teaching, we have got many beneficial experiments, which can be simply summarized as follows. The experimental teaching system is propitious to develop students' creativity and initiative, and improving ability of comprehensively analysing problems. Under the guidance of the teacher, students have to understand the experimental principles and arrange reasonably the order of experiments as well as allocation of time in order to successfully achieve the desired results [21,22]. This greatly inspires the student's enthusiasm and initiative, and changes their passive role as the active one.

The recent experimental teaching system closely follows the development of disciplines, reflecting the characteristics of the time. Additional molecular genetics basic experimental content is needed for scientific and social development. For example, some medicine tests such as the paternity test and detection of some genetic diseases, have adopted the molecular biologic method; in industrial and agricultural production, good plant and animal species identification, identification of environmental microorganisms, also have adopted the methods of molecular biology. Therefore, these technique works are very essential for students to do the future jobs with the universal values of application [23]. In the process of instructing students, sectional experimental teaching guidance is in line with the characteristics of students in skills formation. Some simple parts of experimental operations can be demonstrated through multimedia technology to make the process simple and clear and meanwhile to reduce the experimental steps on guidance, saving teaching hours. However, the students have to practice over and over again to form skills. To approach a greater impact, students should be guided by teaching-assistants, and they can communicate with each other much more easily, since their age and interests are similar. For undergraduate students with active thinking and superb skills, they can apply for a "science and technology pioneer" project to get more exercise for further study with the help of graduate teaching-assistants and teachers. At the same time, for graduate teaching assistants, their research capacity and skills have also been exercised. It must be noted that to build research-oriented pilot program. Students must have certain basic skills, and thus follow the process from the simple to the complex. In different schools and different professions, teaching plan should be arranged scientifically and reasonably. It is envisaged to increase the quality and effectiveness of genetic teaching, hopped as a guide, which requires further thinking and discussion.

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