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Innovation and Practice of Blended Teaching in Molecular Biology Experiments Based on Self-Built Online Courses

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Abstract: Molecular Biology Experiments is a core foundational course for biology majors, playing a crucial role in cultivating students' practical abilities and research literacy. In response to the problems of abstract and difficult-to-understand principles, poor demonstration effects, low student participation, and single evaluation methods in traditional teaching, this study is based on the actual situation of local colleges and universities, and carries out systematic teaching reform practices based on the teaching conditions of our school. By building a "dual teacher" teaching team, optimizing the three-level experimental project system of "basic comprehensive expansion," constructing a hybrid teaching mode based on self-built online courses and virtual simulation platforms, and implementing a diversified assessment and evaluation mechanism throughout the entire teaching process, students' learning initiative has been effectively stimulated, and their self-learning ability, experimental operation level, and comprehensive problem-solving ability have been significantly improved. This reform provides a replicable and operable practical path for local universities with similar teaching resources to carry out molecular biology experimental teaching.

Keywords: Molecular biology experiments; Blended learning; Reform in education; Local colleges and universities

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1. Course introduction

Molecular Biology Experiments is an important practical foundation course for biology majors. Molecular biology techniques cover animals, plants, microorganisms, and other aspects. Our laboratory mainly uses mangrove plants in western Guangdong as experimental materials to carry out basic molecular biology techniques such as DNA and RNA extraction and identification, polymerase chain reaction (PCR), preparation of competent cells, and extraction and transformation of plasmid DNA. At the School of Life Science and Technology of Lingnan Normal University, this course is offered with different hours based on different professional talent training programs, including 32 credit hours for Biological Science, 24 credit hours for Biotechnology, and 16 credit hours for Marine Resource Development Technology. By learning

how to combine theoretical knowledge with practical phenomena, students can cultivate basic experimental skills and rigorous research attitudes in molecular biology, thereby improving their ability to analyze problems comprehensively. This is the foundation for further studying courses such as genetic engineering, bioinformatics, and molecular genetics, and lays a foundation for undergraduate students to engage in molecular testing-related work and continue their studies after graduation. The curriculum team of the School of Life Science and Technology at Lingnan Normal University has improved students' self-learning and innovation abilities through the integration of online and offline teaching reforms, realizing a new practical teaching model that combines online self-learning and offline cooperative learning [1].

2. Problems in experimental teaching of molecular biology

2.1. Teacher's teaching aspect

The traditional teaching method of experimental courses is generally that the teacher explains the principles of the experiment, the precautions for operation during the experiment, demonstrates how to operate the experiment, and finally the students conduct the experiment under the guidance of the teacher. This traditional teaching method generally suffers from poor subjective initiative in students' classroom performance, limited interaction between teachers and students, and a lack of students' ability to think independently [2]. It may be suitable for teaching relatively simple experimental courses, but molecular biology experiments have the characteristics of complex operation and high requirements for the experimental environment. Students need to fully understand what the next step of the experiment should be and why it should be done. If traditional teaching methods are used in the course, teachers will encounter the following problems: 1. The principles of many experimental courses in molecular biology are obscure and difficult to understand, and students only have a partial understanding of what they hear. For example, in our most basic plant DNA extraction experiment, the textbook teaches that DNA is formed by two parallel multiple nucleic acid chains that form a double helix structure, and bases are connected by hydrogen bonds A-T and C-G through hydrogen bonds Pairing principle connection, the skeleton is composed of alternating arrangement of phosphate and deoxyribose, but the extracted DNA can only emit one fluorescent band under ultraviolet light, which is not as vivid as textbooks or popular science videos, and students may not understand it; 2. The experimental operation is highly refined. Due to the large number of people in the teaching process, some students may not be able to see clearly when the teacher gives a demonstration because they are too far away. Even if they can see clearly at that time, it is impossible for unfamiliar people to remember every point they pay attention to. For example, for the most commonly used pipette in molecular biology experiments, we explain its structure and usage to students in detail before the start of the course. When using it, students often do not remember how to check the range, how to choose which range to use, and always forget that the pipette has two stopping points and does not return to the maximum range after use. This results in the teacher repeatedly explaining the same problems to students during the experimental course, which consumes a lot of money. Time and energy; 3. Molecular biology experimental sessions are typically lengthy, which poses a challenge for students to maintain sustained concentration throughout the entire class. For example, the PCR amplification experiment may take about 4 hours from the beginning of the experimental course to the result detection. As we all know, a long classroom time can lead to a decrease in students' learning efficiency and attention, and a deterioration in teaching effectiveness.

2.2. Student learning

The ultimate goal of experimental course teaching is for students to master experimental techniques, and whether students truly master and flexibly apply them is the most important basis for testing the effectiveness of experimental course teaching. I started managing the molecular biology laboratory in July 2016 and began teaching molecular biology experimental courses in September of the same year. Based on my observations over the past few years, I have found that students mainly have the following problems in learning molecular biology experimental courses: 1. Weak theoretical knowledge: This is mainly because molecular biology involves a large number of abstract concepts and complex systems, and students' theoretical knowledge is not solid enough to easily make logical errors in experimental operations, leading to experimental failures; 2. The experimental operation requirements are high, and slight carelessness can easily lead to errors: Taking polymerase chain reaction (PCR) as an example, when preparing the PCR system, the most commonly used one is a 10 μL pipette. If preparing a 20 μL system, the amount of primers added is generally 0.5 μL. Many students may miss the primers (due to the small amount not added) and add too many primers (using the pipette incorrectly), resulting in unsatisfactory experimental results; 3. The experiment has relatively high requirements for the surrounding environment: for example, in RNA extraction experiments, if students are not careful during the operation, RNA enzyme contamination may occur, causing the experiment to fail; 4. Insufficient ability to analyze experimental results, with most students unable to understand the results. The main reason for this phenomenon is the lack of solid theoretical knowledge, which makes it difficult to combine theoretical knowledge with experimental results for analysis. 5. Many students do not do pre-class preparation, or some do pre-class preparation, but the effect is not ideal. Classroom explanations and operational demonstrations cannot be reproduced, making it difficult for students to learn repeatedly [3].

2.3. Teaching conditions

The School of Life Sciences and Technology at Lingnan Normal University is located in western Guangdong. Compared with other educationally developed regions such as the Pearl River Delta, our school has relatively limited teaching resources, mainly manifested in two aspects. Firstly, the teaching budget is limited. In recent years, molecular biotechnology has developed rapidly, and many traditional experimental methods have been replaced by more advanced technologies. However, due to the limitation of experimental funding, many teaching experiments still continue to use traditional experimental methods, which has caused a lag in education. For example, many domestic universities use real-time fluorescence quantitative PCR as a course experiment for undergraduate students. However, we cannot afford the high cost of reagents and consumables, so we can only let students do ordinary PCR. However, when students graduate and work in this field, such as medical testing, they generally need to use real-time fluorescence quantitative PCR. The most typical case is that real-time fluorescence quantitative PCR technology is used in the detection of COVID-19, which creates a gap between the system of students and the reality of the industry; Secondly, the instruments and equipment are very old. In the molecular biology laboratory of the college, many instruments have a service life of over ten years, and some are even close to twenty years. For example, the service life of the gel imaging system in the laboratory has reached 19 years, and the effect of observing agarose gel is particularly poor. Students can hardly see the results after extracting plant DNA. Further determination through PCR will seriously affect the teaching effect. Some more advanced precision instruments, such as fluorescence quantitative PCR, protein purification systems, and other precision large instruments, students

can only imagine through the teacher's description and schematic diagrams in books. The lack of hardware to some extent restricts students' ability to practice hands-on and explore innovation, and also forces teachers to rely more on traditional teaching methods. Under current conditions, we can only make the best use of existing resources, optimize traditional experimental methods, and provide in-depth explanations of experimental principles to enable students to master basic molecular biology and biotechnology as much as possible, laying a solid foundation for their future entry into society.

3. Improvement measures

The rapid development of molecular biology experimental technology has put forward higher requirements for teachers and students. In order to enable students to master molecular biology experimental skills proficiently, improvements have been made in the following areas based on the actual situation of the school and the needs of students.

3.1. Teaching staff

Molecular biology experiments are a practical course that connects theory and application. Students need to carry out practical operations during the learning process, and teachers are the guides of the experimental process. The level of their teaching directly affects teaching effectiveness. Therefore, enhancing teachers' professional abilities is the key to experimental teaching reform, and schools should continuously improve teachers' teaching and research levels through various approaches, such as training programs, professional development workshops, and participation in educational reform projects [4]. Molecular biology experimental teaching requires teachers to not only have solid theoretical knowledge but also proficient experimental operation skills, and to keep up with the latest research techniques in molecular biology experiments. At the same time, it is important to be careful and promptly identify various problems that students encounter during experimental courses, and to have the ability to handle these issues.

In recent years, under the leadership of senior professional title teachers and the support of schools and colleges, the construction of molecular biology courses has been continuously improved, and its teaching staff has also been expanding. At present, the Molecular Biology Experimental Course Group is composed of 8 teachers, including 3 professors, 1 associate professor, 1 lecturer, 1 experimenter, and 1 assistant experimenter. Among them, 5 people have doctoral degrees, and the team construction is reasonable. In addition, our team has a retired professor as an expert to provide guidance and support, and the faculty structure is reasonable. Young and middle-aged teachers are the main force in the molecular biology experimental course; therefore, the curriculum team's graduate training program pays special attention to the cultivation of young and middle-aged teachers. By providing training and guidance for teachers at different levels, we aim to help them improve their professional competence and teaching ability, continuously expand their knowledge base, and enhance their teaching and research capabilities. In the cultivation process, emphasis is placed on fostering teachers' sense of educational responsibility and innovative spirit, encouraging them to actively participate in teaching and research activities, and improving their overall quality. The ability of the curriculum teaching team is constantly improving, and young and middle-aged teachers are developing well. Among them, 3 people have been selected as high-level talents under the "Yang Fan Plan" in Guangdong Province, 1 person has been named a school level teaching master, 1 person has been named a school level

teaching promotion teacher, 2 people have been named school level teacher ethics models, 1 person has been named an excellent teacher in ideological and political courses at the school level, 1 person has won the second prize in the school level young teacher teaching competition, and 1 person has been selected for the cultivation and creation of the "Double Leaders" teaching staff party branch secretary studio in Guangdong Province's universities. It is precisely thanks to this well-structured and capable 'dual teacher' teaching team that we have been able to successfully complete the recording of school-based online course resources, fine management of blended learning activities, and effective implementation of process evaluation.

3.2. Reasonable course design

By optimizing experimental projects, adding comprehensive and expanded experiments, basic experiments cultivate students' ability to use commonly used molecular experimental instruments and pay attention to basic molecular experimental operations. Comprehensive experiments consolidate students' understanding of molecular experimental knowledge, and expanded experiments improve students' molecular experimental operation level. Through this progressive course learning method, students' hands-on ability and learning interest are significantly enhanced[5]. According to the teaching conditions of the school and the learning needs of students, the following experimental courses (as shown in **Table 1**) are offered, and corresponding course requirements are set to achieve better teaching results.

Table 1. Molecular biology experimental course projects

Type	Experiment name	Require mastery of skills
Basic Experiment	Plant DNA extraction	1. The teacher provides laboratory safety education, and students gradually understand how to use molecular biology laboratories safely; 2. Under the guidance of the teacher, become familiar with various specifications of pipettes and learn how to use them correctly; 3. Under the guidance of teachers, learn the correct use methods and precautions of common instruments (high-speed freezing centrifuge, electrophoresis apparatus, electrophoresis tank, gel imaging system, etc.) in molecular biology laboratory; 4. Learn how to read experimental results and how to analyze them.
	Plasmid DNA extraction	
	Detection of DNA by agarose gel electrophoresis	
comprehensive experiment	Plant RNA Extraction, Reverse Transcription, and PCR	1. Able to independently use commonly used instruments and equipment during the experimental process; 2. According to the experimental steps, independent experiments can be conducted; 3. Can understand experimental results and independently analyze them.
	Transformation of Escherichia coli competent cells with plasmid DNA	
Expansion Experiment	Amplification, enzyme digestion, and ligation of gene fragments	1. Can independently design experiments; 2. Ability to independently complete experiments; 3. Can independently solve various problems that arise during the experimental process.

3.3. Change the teaching method

With the development of the times, the traditional experimental teaching mode can no longer meet the needs of teaching. Research has found that blended online and offline teaching has better effects. For example, Wang Yinghua and others have achieved a blended teaching mode of "pre-class self-study + in-class practical operation + post-class review" by building three major platforms: DingTalk, WeChat, and virtual simulation,

significantly improving students' learning initiative and experimental operation ability [6]. In order to better adapt to the development of the times, our school's molecular biology experiments will shift from traditional teaching methods to blended online and offline teaching starting from 2022. In recent years, there have been many related videos online for molecular biology experimental courses. Due to the differences in experimental equipment, reagents, and consumables between local universities and top universities, many mainstream online experimental courses related to molecular biology that have been released are difficult to directly apply. Therefore, building school-based online course resources that are highly compatible with the experimental conditions of our school has become a prerequisite and key to achieving blended learning reform. In order to better serve the teachers and students of our school, the Molecular Biology Experimental Course Team has recorded corresponding experimental courses based on the teaching conditions of our school, and launched them online on Good University Online at the end of 2021 (https://www.cnmooc.org/school/course/index.mooc?checkEmail=false). In September 2022, the school signed a curriculum construction agreement with the Guangdong Hong Kong Macao Greater Bay Area Open Curriculum Alliance. After improvement, the course will be offered in the Guangdong Hong Kong Macao Greater Bay Area Open Curriculum Alliance (http://mooc1.gdhkmooc.com/course-ans/courseportal/221850975.html), and synchronize to the learning platform Learning Platform (https://mooc2-ans.chaoxing.com/mycourse/tch?courseid=221850975&clazzid=60726158&cpi=226470502&enc=90132f2d3ff1b360c10ef660cc80501c&t=1667467465318&pageHeader=8&v=2). Students can better master experimental techniques by repeatedly watching practical content related to experimental courses through any of these three platforms. The content of online courses will also be regularly updated according to the laboratory conditions, and a new content section—virtual simulation experiments—will be added in the future.

3.4. Set reasonable scoring criteria

The ultimate goal of curriculum construction is to enable students to master knowledge and skills; therefore, it is very important to do a good job in evaluating experimental teaching. To directly solve the problems of "insufficient student initiative" and "unclear operation demonstration," this reform has specially designed an assessment system that runs through "pre-class, in-class, and post-class." For example, the "online preview" assessment ensures the early completion of principle learning; The assessment of "classroom operation" directly evaluates and promotes the standardization of students' hands-on skills; The assessment of 'post class discussion' has improved students' subjective initiative; The 'Experimental Report Writing' assesses whether students can combine theory with practice. Starting from 2022, the Molecular Biology Experimental Course has adopted a blended online and offline teaching model and developed clearer grading rules (**Table 2**), including: pre-class preparation before class, online and offline teaching in class, online discussion after class, and correction of experimental reports, in order to achieve better learning outcomes.

Table 2. Scoring rules for molecular biology experiments

Grading criteria		Scoring rubric Various scores	Score	
			Various scores	Total score
Before class	Online preview	Before class, preview the relevant experimental content on the Learning Platform (teachers give scores based on students' preview status on the platform)	10	10

Classroom performance	Attendance	Late arrival or early departure may result in deduction of points, while absenteeism in the experimental project will result in 0 points	5	35
	Listening status	Did you pay attention to listening during class (small class teaching, with each student's name posted on the seat)	10	
	Experimental operation	Can experimental instruments and equipment be used correctly, and can experiments be operated correctly under the guidance of teachers	20	
After class	Experimental report writing	Whether the experimental results and analysis are accurate, whether the experimental report is written completely, whether the format is standardized, and whether the thinking questions are answered correctly	30	55
	Online homework	Whether the online homework is completed on time and whether the answers are correct	15	
	Online discussion	Do you participate in online discussions	10	

4. Conclusion

This article proposes a series of reforms and practices to address the practical problems in the teaching of molecular biology experiments at the author's school. Firstly, we have provided a core guarantee for teaching reform by building a well-structured and capable teaching staff. Secondly, the experimental projects were designed in a layered manner, forming a curriculum system from basic to comprehensive and then to extended, meeting the progressive learning needs of students. Furthermore, by fully utilizing modern information technology, building school-based online course resources, and implementing blended online and offline teaching, the limitations of traditional teaching in time and space have been broken, achieving personalized and repetitive learning for students. Finally, the assessment method was reformed, and a comprehensive evaluation system combining process evaluation and summative evaluation was established, which comprehensively and objectively reflects students' learning outcomes. Practice has shown that these reform measures have significantly stimulated students' learning motivation, strengthened their hands-on ability and innovative thinking, effectively promoted the improvement of talent cultivation quality, and provided a reference paradigm for molecular biology experimental teaching in applied undergraduate colleges. In the future, the curriculum team will continue to improve online resources, deepen the integration of ideological and political education into courses, and explore the deep integration of new technologies such as artificial intelligence with experimental teaching to continuously enhance the quality of courses.

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Disclosure statement

The authors declare no conflict of interest.

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