Journal of Contemporary Educational Research, 2025, Volume 9, Issue 9
http://ojs.bbwpublisher.com/index.php/JCER
ISSN Online: 2208-8474
ISSN Print: 2208-8466

# Exploration and Application of AI Technology in Molecular Biology Experimental Teaching

**Ying Zhang*, Weijin Li, Liyun Wang, Danfeng Li**

School of Life Science and Technology, Lingnan Normal University, Zhanjiang 524048, Guangdong, China

**Author to whom correspondence should be addressed.*



**Abstract:** Artificial intelligence (AI) technology is increasingly used in the field of education, but its application in molecular biology experimental teaching still faces challenges. In order to explore the application prospects of AI technology in molecular biology experimental teaching, this paper discusses the application of AI technology in molecular biology experimental teaching, focusing on the construction and application of virtual laboratories. At the same time, the advantages, challenges and future development directions of AI technology application are analyzed. The study found that AI technology has broad application prospects in molecular biology experimental teaching. AI technology can overcome many limitations in traditional experimental teaching, and can also provide personalized learning experience, real-time feedback and evaluation, and simulate complex molecular processes. However, the application of AI technology also faces challenges such as technology cost, teacher training, and curriculum design. In summary, the application of AI technology in molecular biology experimental teaching has significant advantages and can effectively improve teaching quality and learning effects. In the future, we should strengthen the integration of AI technology and traditional teaching methods, develop more AI teaching tools suitable for the characteristics of molecular biology, and focus on cultivating students' practical ability and innovative thinking. This study provides new ideas and directions for promoting the reform and innovation of molecular biology experimental teaching.

**Keywords:** AI technology; Molecular biology experiment; Virtual laboratory; Teaching reform

**Online publication:** Oct 22, 2025

## 1. Introduction

With the rapid development of Artificial Intelligence (AI) technology, its application in the field of education has become increasingly widespread. In February 2024, Nanjing University launched a "General Core Curriculum System for Artificial Intelligence" for all undergraduate freshmen; Southeast University has built the country's first fully domestically produced integrated cloud-intelligence computing platform; and in June, Nanjing University of Posts and Telecommunications released an "AI + Innovative Talent Cultivation" action plan [1]. Following the rising popularity of DeepSeek, Lingnan Normal University has actively promoted the development of AI + courses on campus. As an important branch of life sciences, molecular biology relies heavily on experimental teaching for students to understand and master relevant knowledge. However, traditional experimental teaching of molecular biology faces numerous challenges: expensive experimental equipment and high costs of reagents and consumables limit students' opportunities for independent operation and repeated practice; complex experiments (such as plasmid construction and cell culture) with long cycles [2] result in students spending a great deal of time on repetitive operations rather than thinking and innovation; experiments involve toxic and harmful reagents (e.g., EB) and precision instruments, posing certain safety risks and making management inconvenient [3]; and most notably, the lack of personalized guidance—large-class teaching makes it difficult for teachers to provide targeted instruction and feedback to each student. The introduction of AI technology offers new ideas and methods to address these issues. In October 2024, the Molecular Biology Experiment course was approved as one of Lingnan Normal University's first batch of school-level AI + courses.

To promote the orderly development of AI + courses, the university has adopted a number of innovative measures:

(1) Constructing an AI curriculum system by incorporating core courses such as Application of Artificial Intelligence into the compulsory module of general education;

(2) Developing an AI Experience Center that integrates immersive exhibition areas featuring speech interaction and visual recognition to provide a "third classroom" environment for practical teaching;

(3) Launching customized on-campus training programs like the thematic training "How to Be a Teacher in the AI Era", which explains the application of tools such as Doubao and Kimi in teaching and research based on professional needs;

(4) Integrating resources and providing platform support by accessing the DeepSeek large model into the Chaoxing Fanya platform to optimize functions including AI teaching assistant setup, intelligent agent development, and academic performance diagnosis.

These measures have created a favorable environment for the development of the "AI + Molecular Biology Experiment" course, and the course team has actively explored, designed and implemented a comprehensive reform plan for "AI + Molecular Biology Experimental Teaching". This study aims to systematically introduce the top-level design, core application modules, implementation process and preliminary results of this teaching model, in order to provide referable practical experience and theoretical reference for the teaching reform of similar domestic courses.

## 2. Constructing a new model of "AI + molecular biology experimental teaching"

In teaching practice, the course team adheres to the educational philosophy of "student-centered, problem-oriented, and competency-based", and has constructed a blended teaching framework featuring in-depth integration of online and offline learning, as well as combination of virtual and real experiences. With four major AI application modules as its core pillars, this framework aims to reshape the entire process of experimental teaching (**Figure 1**). As shown in **Figure 1**, the "three stages" consist of the pre-class, in-class, and post-class stages, while the "four modules" include virtual simulation, intelligent assessment, intelligent teaching assistant, and data analysis.

The three-stage approach includes pre-class (online preview and simulation): students learn theoretical knowledge through an AI platform and conduct unlimited pre-operations using a virtual simulation laboratory to familiarize themselves with the procedures and predict results; in-class (offline core operation and online intelligent assistance): students enter the physical laboratory to complete hands-on operations of key steps, and can call an AI teaching assistant via mobile terminals at any time to solve practical problems encountered; and post-class (online data analysis and extension): students use AI tools to process and analyze experimental data, write experimental reports, and carry out personalized extended learning based on system recommendations.

The four modules, which run through the above three teaching stages, are: AI-driven virtual simulation experiment platform, AI intelligent teaching assistant and question-answering system, AI-assisted experimental design and data analysis tools, and AI-driven personalized learning and intelligent evaluation system.

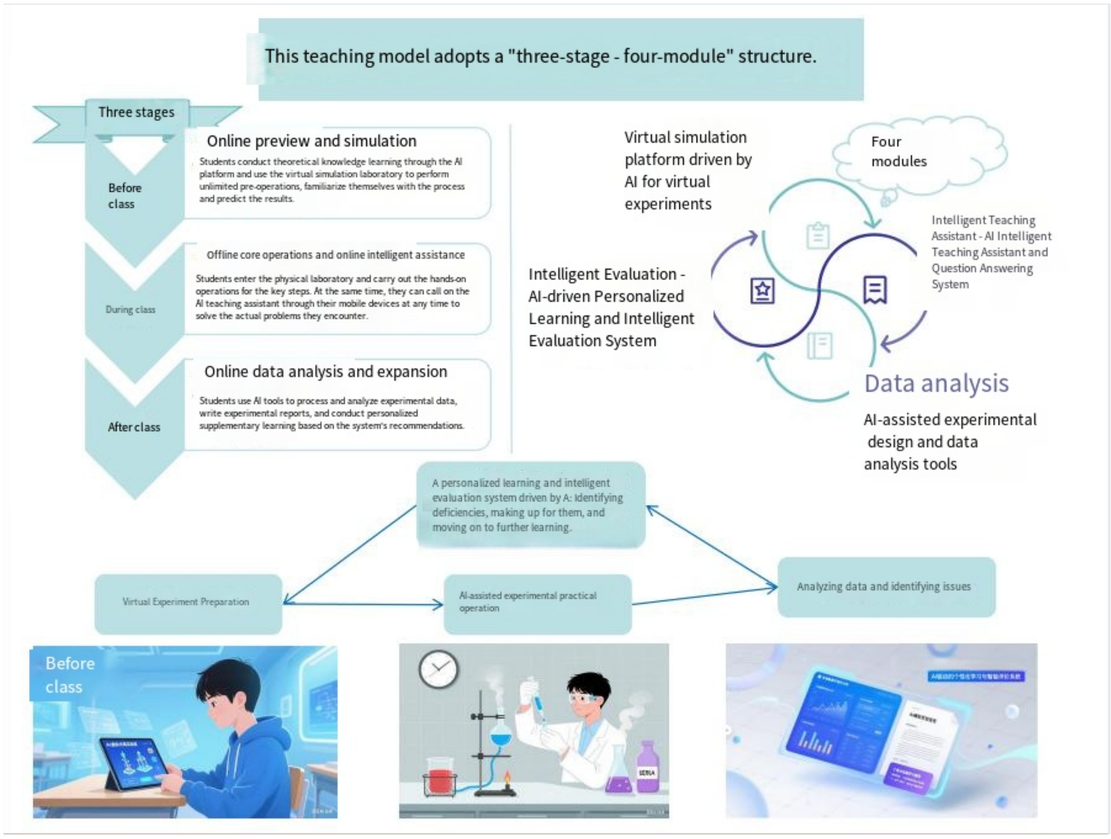


**Figure 1.** Framework diagram of the "AI + molecular biology experimental teaching" model.

## 3. Four modules of the "AI + molecular biology experiment" course

### 3.1. AI intelligent teaching assistant and Q&A system

To provide students with round-the-clock and real-time academic support, we have deployed an AI intelligent teaching assistant based on a large language model. This system integrates mainstream molecular biology textbooks, experimental guides, cutting-edge literature in related fields, and a database of common questions accumulated from years of teaching.

Its functions and advantages are as follows:

(1) 24/7 Instant Q&A: Whenever and wherever students encounter questions about experimental principles, operation steps, or troubleshooting, they can interact with the AI teaching assistant via text or voice to get immediate answers;

(2) Liberating Teachers' Productivity: The AI teaching assistant handles a large number of repetitive basic questions, freeing teachers from tedious Q&A work and allowing them to focus more on curriculum

design, heuristic teaching, and guidance on students' higher-order thinking;

(3) Heuristic Guidance: When students ask open-ended questions, the AI teaching assistant not only provides direct answers but also guides students to think more deeply through follow-up questions, providing links to related concepts, and other methods.

### 3.2. AI-assisted experimental design and data analysis

Free students from tedious and repetitive calculations and data processing, allowing them to focus on experimental design and the scientific interpretation of results, and cultivating their computational thinking and data literacy. Implement intelligent experimental design: for example, AI can intelligently recommend primer design schemes, enzyme digestion schemes, and predict experimental results based on the target sequences of genes input by students. For automated data analysis, students can upload the raw data generated from experiments, and AI tools can automatically identify and generate preliminary data analysis, enabling students to focus their main energy on explaining "what the data means" rather than "how to process the data". AI tools can help students intuitively see how bioinformatics algorithms are applied in practical experimental design and data interpretation, deepening their understanding of computational biology methods [4].

### 3.3. AI-driven virtual simulation experiment platform

The "Molecular Biology Experiment" course at Lingnan Normal University was recognized as a university-level online course in 2019. After long-term development, it was accredited as a Guangdong Provincial First-Class Undergraduate Course (online-offline hybrid first-class course) in 2023. The course has built its own online learning resources and gradually integrated into the National Virtual Simulation Experimental Teaching Course Sharing Platform module. Through virtual simulation experiments, students can conduct immersive operational exercises. Meanwhile, virtual operations do not consume any physical reagents or consumables, completely eliminating safety risks in experiments—making it particularly suitable for teaching high-cost, high-risk, or long-cycle experiments [5]. Students can freely modify experimental parameters (such as annealing temperature and cycle number) and observe the impact of different parameters on experimental results, thereby transforming learning from passive "recipe-style" operation to active "exploratory" research.

### 3.4. AI-driven personalized learning and intelligent evaluation system

Continuously track and analyze students' learning behavior data through the learning management system to implement personalized teaching tailored to individual needs. AI is capable of recommending personalized learning paths. Based on students' operational proficiency in virtual simulations, accuracy rates in online quizzes, and interaction records with AI teaching assistants, the system constructs individual student ability profiles [6]. For weak areas, the system automatically pushes relevant teaching videos, literature reading materials, or additional simulation practice tasks to achieve targeted tutoring. For intelligent process-oriented assessment, the AI system can automatically grade objective questions, evaluate the standardization of virtual operations, and use natural language processing technology to conduct preliminary analysis on experimental reports submitted by students (such as checking data integrity, chart standardization, reference format, etc.), and generate formative assessment reports. This not only improves the efficiency and objectivity of assessment, but also provides teachers with comprehensive data on students' learning processes, facilitating teaching interventions.

## 4. Outcomes and analysis

After a semester of teaching practice, we collected and analyzed relevant data, and the results showed that the "AI + Molecular Biology Experimental Teaching" model has achieved remarkable outcomes.

### 4.1. Significant improvement in learning outcomes

In terms of theoretical knowledge, the average final exam score of the experimental group (87.5 ± 4.3) was significantly higher than that of the control group (81.6 ± 5.2), with $P < 0.01$. In terms of experimental skills, through scoring the videos of offline experimental operations, students in the experimental group scored better than those in the control group in operational standardization, process proficiency and problem-solving ability. In addition, a blind review assessment of the quality of experimental reports from students of both groups showed that the reports of the experimental group performed better in terms of professionalism of data presentation, depth of result analysis and logic of discussion.

### 4.2. Enhanced innovation and practical abilities

Thanks to the opportunities for free exploration and trial-and-error provided by the virtual simulation platform, students in the experimental group demonstrated a stronger desire for inquiry. In the final open experimental design session, the proposals submitted by the experimental group were more innovative and feasible. AI-assisted data analysis tools (DeepSeek-R1-32B + huiya-chat-34-q4 model) enabled students to process more complex datasets and focus on formulating and verifying scientific questions, effectively cultivating their research thinking.

### 4.3. Substantial improvement in learning experience and satisfaction

An anonymous questionnaire survey was conducted among students of both groups. The results showed that the overall satisfaction of the experimental group with the teaching model reached 96%, significantly higher than the 75% of the control group. Students generally reported that the AI teaching model made the learning process more vivid and interesting with more flexible scheduling, and virtual simulation operations effectively alleviated their anxiety about practical operations. The real-time feedback from AI teaching assistants was regarded as "one of the most helpful functions."

### 4.4. Positive teaching efficiency and teacher feedback

The feedback from teachers is also very positive. Teacher questionnaire results show that they believe the AI system has taken on a large amount of repetitive work (such as homework correction and answering basic questions), enabling them to focus more on the overall design of courses and personalized in-depth tutoring for students [7].

## 5. Challenges and limitations in the construction of "AI + molecular biology experiment" courses

### 5.1. Technical costs

Although virtual experiments can reduce long-term teaching costs, the initial technical investment remains high. High-quality VR equipment and software development require substantial financial input [8]. Corresponding solutions include: Governments and schools can increase investment in educational technology to support the application of AI technology in the field of education; Encourage industry-university-research cooperation to jointly develop AI technologies and VR content suitable for education, thereby reducing development costs; Explore sharing models where multiple schools share VR laboratories to split costs. The molecular biology experiment course utilizes the National Virtual Simulation Experimental Teaching Course Sharing Platform, which provides corresponding convenience for virtual experiments in the course, but there are also limitations on the time limit for use.

### 5.2. Teacher training

Teachers are transforming from traditional "lecturers" to "designers, guides, and facilitators of learning". Many teachers lack experience in using AI technologies and VR equipment and require additional training [9], which also increases the current workload of teachers. However, this can be gradually addressed through the following measures: Launch systematic teacher training programs to improve teachers' technical literacy; Establish teacher exchange platforms to promote experience sharing and mutual assistance; Encourage teachers to participate in the development and improvement of AI educational technologies to enhance their understanding and mastery of new technologies. To truly realize the construction of the "AI + Molecular Biology Experiment" course, interdisciplinary close cooperation within the teacher team is required, including not only molecular biology experts but also educational technology experts and computer scientists.

### 5.3. Student adaptability

In the teaching process, some students may not adapt to the VR environment or rely excessively on virtual experiments [10]. It is necessary to introduce VR technology gradually and combine it with traditional experimental teaching methods. Adaptive training courses should be designed to help students gradually adapt to the VR environment. Emphasis should be placed on the combination of virtual experiments and practical operations to prevent students from over-relying on the virtual environment.

## 6. Outlook on the construction of "AI + molecular biology experiment" course

With the continuous development of AI technology, it has broad application prospects in molecular biology experimental teaching. Possible future development directions include:

(1) Multi-sensory interaction: In addition to vision and hearing, introduce multi-sensory interaction technologies such as haptic feedback to further enhance the realism of the experimental experience [11];

(2) AI-assisted experimental design: Use AI algorithms to assist students in designing experimental schemes, improving the innovation and efficiency of experiments [12];

(3) Interdisciplinary integration: Integrate molecular biology with VR experiments of other disciplines (such as chemistry and physics) to promote interdisciplinary learning [13];

(4) Real-time collaborative experiments: Develop VR experimental platforms that support multiple people online simultaneously to facilitate collaborative learning among students;

(5) AI-driven personalized learning paths: Based on students' learning data, AI systems can formulate optimal learning paths and experimental plans for each student.

## 7. Conclusion

Through practice at Lingnan Normal University, this study systematically constructed and verified the feasibility and superiority of the new "AI + Molecular Biology Experimental Teaching" model. Practice has proved that by integrating functions such as AI-driven virtual simulation, intelligent teaching assistants, data analysis, and personalized evaluation, this model effectively overcomes many shortcomings of traditional experimental teaching, significantly improves teaching quality, learning efficiency, and the satisfaction of teachers and students, and shows great potential especially in cultivating students' scientific inquiry ability and innovative thinking.

For experimental teaching, AI technology is by no means a simple tool replacement, but a profound paradigm revolution. It shifts the focus of teaching from the training of repetitive skills to the cultivation of high-order abilities such as data analysis, critical thinking, problem-solving, and knowledge creation. Future experimental teaching will no longer be isolated offline operations, but an intelligent learning ecosystem featuring the integration of virtual and real environments, human-machine collaboration, and data-driven approaches. Certainly, the key to the success of this transformation lies not in how advanced the technology itself is, but in whether we can skillfully integrate technology into the educational philosophy and teaching design centered on student development [14]. Cultivating the next generation of innovative talents in life sciences through the collaborative cooperation between humans and AI is our unremitting pursuit.

## Funding

Construction Project of Teaching Quality and Teaching Reform Engineering for Undergraduate Universities in Guangdong Province (Project No.: 2023-248); First-Class Undergraduate Course in Guangdong Province - Molecular Biology Experiment 2023; Curriculum Ideology and Politics Demonstration Project of Lingnan Normal University (Project No.: 2022-6 & 2024-44); Construction Project of Teaching Quality and Teaching Reform Engineering of Lingnan Normal University (Project No.: 2024-24)

## Disclosure statement

The authors declare no conflict of interest.

## References

[1] Yang P, Ye Z, Xie S, et al., 2024, "Everyone Learns AI": What Exactly to Teach and How?, Xinhua Daily, July 18, 2024.

[2] Morimoto J, Ponton F, 2021, Virtual reality in biology: could we become virtual naturalists?. Evo Edu Outreach, 14(7): 3–13.

[3] Zhang Y, Wang L, Li W, 2023, Exploration on the construction and teaching reform of molecular biology experiment course. China Educational Technology & Equipment, 2023(2): 136–138.

[4] Espinosa C, Becker M, Marić I. et al., 2021, Data-Driven Modeling of Pregnancy-Related Complications. Trends in Molecular Medicine. 2021(27):762–776.

[5] Akhtar M, Anderson M, Cochrane T, 2024, Implementing Augmented Reality and Virtual Reality for authentic healthcare education: Technology enhanced healthcare education for low resource settings with a focus on Australasia. Pacific Journal of Technology Enhanced Learning, 6(1): 2–3.

[6] Christopoulos A, Mystakidis S, Cachafeiro E, et al., 2023, Escaping the cell: virtual reality escape rooms in biology education. Behaviour & Information Technology, 42(9): 1434–1451.

[7] Hazaymeh W, Bouzenoun A, Remache A, 2024, EFL Instructors' Perspective on Using AI Applications in English

as a Foreign Language Teaching and Learning. Emerging Science Journal, 202(8): 73–87.

[8] Avşar G, Çelik Ş, Doğan S, et al., 2024, Virtual Reality Technology in Nursing Education: A Qualitative Study. European Journal of Education, 2024: e12780.

[9] Serin H, 2020, Virtual Reality in Education from the Perspective of Teachers. AMAZONIA, 26(9): 291–304.

[10] Chuang T, Chou Y, Pai J, et al., 2023, Using Virtual Reality Technology in Biology Education: Satisfaction & Learning Outcomes of High School Students. The American Biology Teacher, 85(1): 23–32.

[11] Pedersen K, Musaeus P, 2023, A phenomenological approach to virtual reality in psychiatry education. Frontiers in Virtual Real, 2023(4): 1–18.

[12] Howard M, Davis M, 2023, A Meta-analysis of augmented reality programs for education and training. Virtual Reality, 27(4): 2871–2894.

[13] Niu M, Lo C, Yu Z, 2021, Embedding Virtual Reality Technology in Teaching 3D Design for Secondary Education. Frontiers in Virtual Reality, 2021(2): 661920.

[14] Nash J, 2024, Abstract 1795 Navigating the AI Disruption: Tailoring Teaching for the Future. Journal of Biological Chemistry, 2024(300): 105794–105794.