

Research Article

The Design of Virtual Laboratory of Molecular Biology Based on Flash Technique—Agarose Gel Electrophoresis

Ma Shengjian*, Huang Jialing, He Jintu

Life Science and Technology School, Lingnan Normal University, Zhanjiang, China

Abstract

With the development of information technology, virtual reality technology has been applied to every field of teaching. This paper showed the design process, design concept and content settings of the virtual experiment based on Flash technology, which used the agarose gel electrophoresis as an example, and illustrated the research and development of this kind of virtual laboratory was important to improve the quality of experimental teaching.

Keywords

Molecular Biology, Virtual Laboratory, Flash, Electrophoresis

1. Introduction

Virtual Laboratory was first proposed by William Wolf (1989), which refers to the use of multimedia, simulation, virtual reality and other technologies to create related software and hardware operating environments on computers that assist, partially or even fully replace traditional experimental operations. The purpose is to make Researchers and educators can effectively use relevant data, information, equipment, human resources and other resources to engage in scientific research and education activities [1]. According to the degree of immersion in virtual reality technology, virtual experiment systems can be divided into "desktop virtual experiment systems" and "immersive virtual experiment systems" [2].

Molecular biology is a highly experimental subject. The cultivation of students' experimental skills plays a very important role in improving their hands-on ability, observation, analysis and problem-solving abilities. On-site experiments require expensive experimental equipment and a large amount of chemical

reagents and equipment, some of which are toxic. In recent years, the enrollment scale of colleges and universities has continued to expand, experimental funds and venues have become more restricted, and problems such as insufficient practical teaching conditions and aging equipment have become increasingly serious [3]. Therefore, using the virtual experiment system to create an experimental platform that allows students to learn at any time is of great significance to solve problems such as insufficient on-site experimental teaching, teaching development in special periods such as quarantine management due to virus epidemics, and distance education for all. [4-6]. This paper uses Flash technology to design a "desktop virtual experimental system" for agarose gel electrophoresis, which can allow students to use the virtual environment to get familiar with the whole experimental process, reduce the operation error in the actual experiment, and has great application value.

*Corresponding author: mashengjian1@163.com (Ma Shengjian)

Received: 17 November 2024; **Accepted:** 27 November 2024; **Published:** 12 December 2024



Copyright: © The Author(s), 2024. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

2. Design and Related Techniques of Virtual Experiments on Agarose Gel Electrophoresis

2.1. Design Object

The experiment is designed for undergraduate students who offer experimental courses in molecular biology.

2.2. Design Objectives

To design the virtual experiment, the first step is to use its vivid animation effect to simulate the experimental operation process, so that students can be familiar with the overall experimental environment and experimental steps in advance, so as to make full preparation for entering the efficient completion of the experiment in the real laboratory. Secondly, the design interface should be scientific, intuitive and neat, try to meet the needs of students experiments, let students quickly find the button in the operation process, accurately and effectively carry out the experiment, and play the purpose of auxiliary experimental teaching.

2.3. Research and Development Process

2.3.1. Analyze Experimental Principle and Experimental Process

Master the experiment reagent use and instrument working principle, study each experimental step, analyze the mutual relationship between the experimental steps and considerations, and the analysis of reagent preparation, application and the structure of the instrument, state and operation steps, refining key steps, decomposition operation details, for animation design and drawing realistic experimental equipment and operation fully prepared.

2.3.2. Draw the Experimental Instruments

Two-dimensional vector graphics are generated by software.

In order to restore the real graphics of the experimental equipment, try to pay attention to the depiction of every detail, including the structural proportion of each instrument, the color material of each component, the range of the pipette gun, the data display and buttons of the electrophoresis instrument screen, etc. (Figure 1). Moreover, each part is relatively independent, facilitating subsequent animation Settings and modification updates.

The main reagents and equipment involved in the DNA sample separation experiment of agarose gel disk electrophoresis include various agarose, electrode liquid, pipete gun, atmospheric voltage electrophoresis apparatus, electrophoresis tank, etc.



Figure 1. An electrophoresis apparatus.

2.3.3. Preparation of Experimental Procedure

The steps of the experiment are placed in a film clip element named as the experimental process, and placed in the timeline keyframe of the main scene in the form of a movie clip. The experimental steps in the film clip can be summarized and decomposed into each layer of the relevant folder (Figure 2). In addition to the layers of the experimental process in the main scene, it also places the background environment and interactive buttons of the virtual laboratory, so that the complicated experimental steps in the experimental textbook are organized and concise, which is conducive to students understanding and operation.

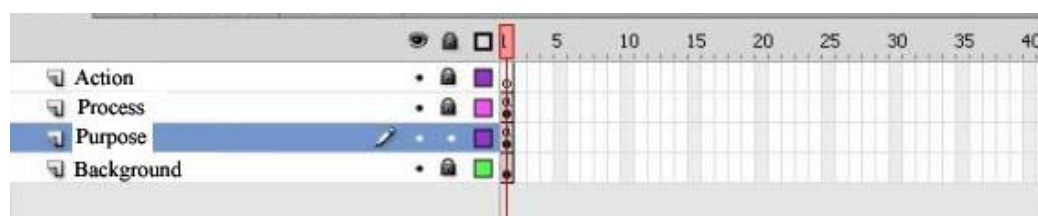


Figure 2. Timeline situation of the movie clips during the experiment.

Electrophoretic separation experiments included prepared gels, sample loading, electrophoresis, observation and analysis of results. The key step is the preparation of agarose gel,

which includes weighing the agarose powder, measuring the electrode buffer solution, heating and boiling the gel, adding fluorescent stain, filling the gel and pulling out the baffle.

Some of the experimental equipment in the animation is relatively small, which can be better solved by making the parts of the virtual laboratory scene clearer.

In order to solve the problems of the liquid storage bottle, the glass tube and the triangle bottle for glue making, the rising state of the pipette and the rubber head dropper, the stereo feeling of the solution in the beaker, and the glue situation of the liquid when absorbing the reagent, and make the whole experimental process more vivid, the following techniques are adopted:

When drawing liquid storage bottles and other equipment, the color should be set with different levels of transparency. Frame-by-frame animation technology is used to depict the countdown scene waiting for gel aggregation.

The interroom animation technique is used to depict the delicate liquid level rising action and the action of shaking the triangle bottle, so that it produces a natural three-dimensional sense.

Add sound effects to foil the animation atmosphere, and use the recorded sound to show the rise of the liquid level in the pipette when absorbing the solution and the shaking feeling of the beaker during the mixture.

Through the clever use of these animation techniques, the "gel preparation" to achieve a three-dimensional dynamic

audio-visual effect. Other steps shall be solved by different technologies according to the specific requirements. In short, in the production process, various animation technologies are flexibly used to solve practical problems scientifically and reasonably, so that the animation rhythm is as far as possible in line with the actual operation, the animation sound effect is more realistic, in order to enhance the appeal of virtual experimental animation, shorten the distance with the users, and play the role of icing on the cake.

3. Main Contents of the Virtual Experiments with Agarose Amide Gel Electrophoresis

3.1. Content Settings and Composition

The experiment content includes the following six sections: experimental purpose, experimental principle, reagent equipment, experimental steps, precautions and discussion, plus the instrument that can directly click on the experiment operation on the desktop [7].

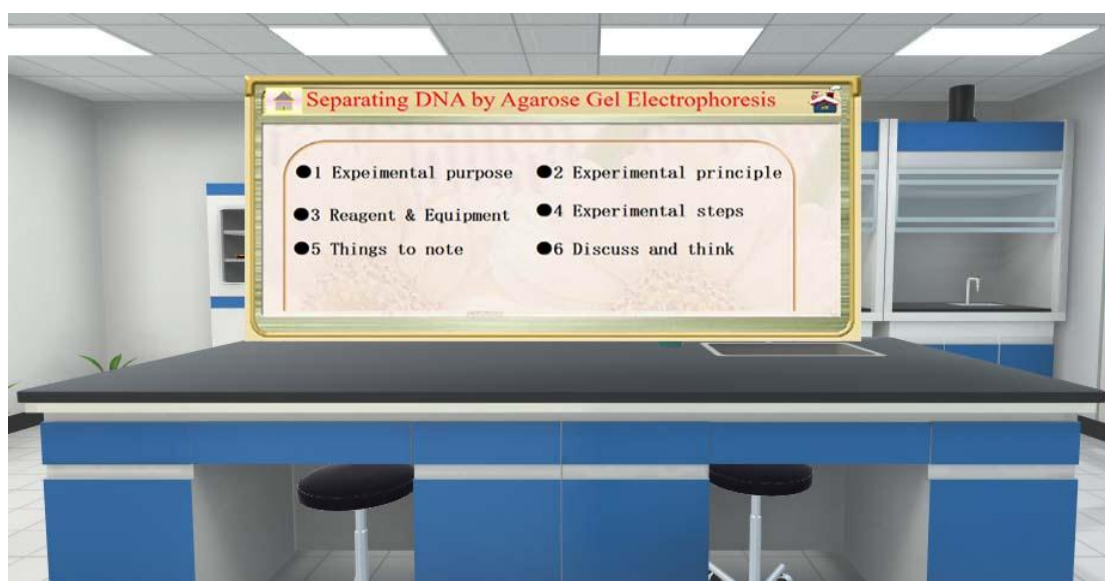


Figure 3. The overall environment of the virtual laboratory.

In order to create a virtual state for students to be immersive, intuitive and convenient to operate, the interactive option button of the six plates is set on the blackboard (Figure 3). Students can pop up the corresponding content by directly

clicking the circular button on the blackboard. Some text content exceeds the boundary of the blackboard, can be set by the right pull the bar. To leave the current plate, just click the back button to go back to the original interface (Figure 4).

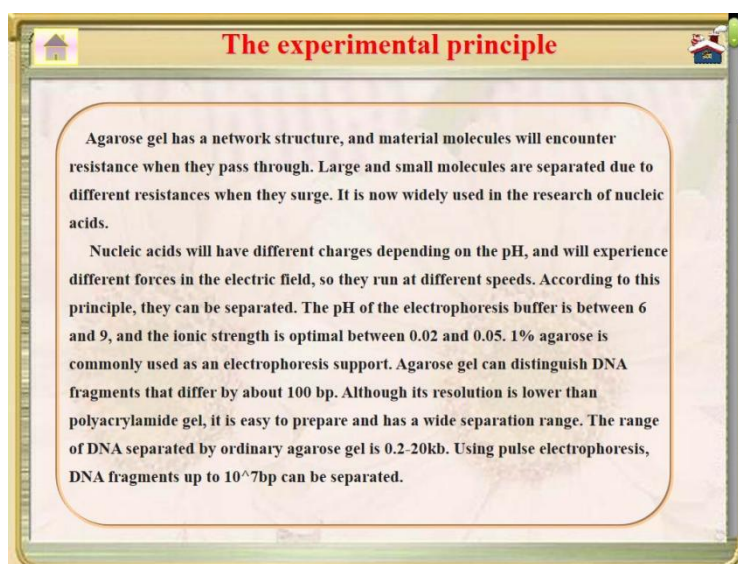


Figure 4. The corresponding content that pops up after clicking the button in the experimental principle section.

Before starting the experiment, students should first understand the relevant knowledge and key points and difficulties of the experiment, and avoid blind clicking when operating the virtual experiment. When you forget the next step during the experiment, you can click the button in the operation step section to view the specific content description in time. Discuss the content of the thinking section can be prepared before the experiment, and the learning effect will be better with the questions, or after the experiment.

3.2. Experimental Illustration

In the agarose electrophoresis separation experiment, the purpose describes the techniques and key concepts, the properties and applications of the gel and the required experimental equipment, which have been shown on the desktop of the virtual laboratory, and the experiment process is decomposed into five steps: gel preparation, sample loading, electrophoresis, observation and result analysis [8]. The title of each step is linked to the corresponding experimental operation animation, including the operation steps with detailed text description. Notes are some problems that students should pay attention to before or during the experiment, such as agarose gel should be ready and used, which are also reflected in the experimental operation animation.

4. Application Advantages of Virtual Laboratories in Experimental Courses of Molecular Biology

4.1. Enhance the Students Experimental Preview Effect

Many molecular biology experiments are complicated and

difficult to understand, just like agarose gel electrophoresis. If students do not preview the principles and methods of the experiment, it is difficult to master the corresponding experimental operation in class and complete the experiment independently. However, students only study independently with the help of experimental teaching materials, and the preview effect is very poor, and teachers still need to tell and emphasize repeatedly, especially in some complex operations, it is difficult for students to have practical experience. Students can use the practice of virtual laboratory before class, not only can master the use method of atmospheric voltage electrophoresis instrument, but also can experience the whole operation process, forming a profound memory, and the operation efficiency of the experiment class will be greatly improved.

4.2. Strengthen Students Basic Skills in Molecular Biology Experiments

Agarose gel electrophoresis experiment is to let students master the basic principle and operation technology of electrophoresis, which is the content of molecular biology experiment. However, in the experimental class, it is often found that the students basic skills are poor, which seriously affects the experimental effect. Therefore, before the experimental class, students enter the virtual laboratory and get familiar with some basic operations, which is conducive to improving students operational skills and hands-on ability.

4.3. Reduce the Consumption of Equipment and Drugs

In many experimental processes of molecular biology, a large number of chemical reagents and expensive experimental equipment need to be used, and some reagents both

cost money and are somewhat dangerous. Virtual experiments can greatly reduce the use of reagents, which can not only save costs, but also reduce the impact of reagents on operators and environmental pollution from chemical waste.

5. The Deficiencies and Problems of the Virtual Laboratory

The virtual experiment of agarose gel electrophoresis is easy to operate. The courseware can be used on any computer that can open SWF format files. Instead of the traditional face to face teaching mode, students can use the computer for experimental operation at any time. However, because the virtual laboratory is still in the development stage, it can only exist in the form of a single machine, which is still insufficient in terms of interactivity. To fully realize teaching resource sharing, also should be on this basis to continue to study and explore, the experiment teaching material has not yet developed experiment design, will develop a variety of technology mutual fusion, strengthen the virtual laboratory collaboration, adaptive research, committed to build good simulation, practical virtual experiment teaching system.

Teachers use the virtual experiment courseware to display, which can deepen students understanding, guide the positive thinking of experimental phenomena and explore problems, and achieve the expected teaching goals. However, the virtual experiment cannot be completely practical, but is only an auxiliary means of teaching. Because the experimental operation of virtual experiment is done by clicking or moving the mouse, in a sense, it has no direct effect on cultivating students experimental skills; and sometimes the actual operation and virtual experiment are still different. Therefore, the ratio of virtual experiment to actual experiment must be reasonably arranged according to different experimental subjects to combine the two organically [7, 8].

When using the virtual laboratory for distance teaching, the following questions: (1) how to change the teacher-centered experiment mode into the student-centered experiment mode, fully reflect the constructivist learning theory; (2) how to evaluate the experiment results and evaluate the effect of virtual experiment; (3) how to determine the position of teachers in the experiment, make it from the organizer to the guide.

Of course, the development prospect of the virtual laboratory is bright. With the further development of Internet and its rapid spread around the world, a new round of revolution in the traditional education model. Modern educational technology characterized by network is an important support for distance education, which will certainly promote the progress of all kinds of information education technology, and will also bring a subtle influence on the social and economic form structure and cultural education system [9-12]. The development of virtual laboratory belongs to the category of modern network education, which will provide new resources for

the distance education that people need [13-15].

Abbreviations

SWF Shock Wave Flash

Author Contributions

Ma Shengjian: Funding acquisition, Investigation, Writing—review & editing

Huang Jialing: Conceptualization, Methodology, Writing—original draft

He Jintu: Project administration, Software

Funding

This research was funded by the Program of the Guangdong Provincial First-class Specialty construction "Biological Science" (Guangdong Provincial Higher Education Letter No. 14, 2022) and Guangdong Provincial Undergraduate University Teaching Quality and Teaching Reform Project "Life Science Multidisciplinary Special Talent Training Plan" (Guangdong Provincial Higher Education Letter No. 4, 2023).

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Enrique Canessa; Carlo Fonda; Sandro M. R. Virtual Laboratory Strategies for Data Sharing, Communications and Development [J]. Data Science Journal, 2002, 1 (8): 248-256. <https://doi.org/10.2481/dsj.1.248>
- [2] T. O. Levytska; O. Y. Piatyko; O. A. Khliestova; A. P. Bilenko. Virtual laboratories for study technologies of environmental protection [J]. Journal of Physics: Conference Series. 2024, 2871(1): 012025-012025. <https://doi.org/10.1088/1742-6596/2871/1/012025>
- [3] Liang Yilong, Lu Liping, Fan Huan, et al. Application of virtual experiments in teaching biochemistry experiments [J]. Laboratory Science, 2012, 15(2): 45-46. (In Chinese).
- [4] Eduardo F. Damasceno; Larissa B. Fernandes; Armando P. Da Silva; Sara T. Moreira. An Evaluation of Immersive Laboratory in Microbiology Teachings [J]. Creative Education. 2024, 15(8): 1718-1732. <https://doi.org/10.4236/CE.2024.15810410.2481/dsj.1.248>
- [5] Wu Fati, Hu Yihong. Design and implementation of a virtual laboratory based on Flash technology [J]. Education Informatization, 2006: 43-44. (In Chinese).
- [6] Carolyn M Audet; Lance J Roller; Muktar H Aliyu; Lori

- Rolando; Maria Alva; Mohammad Ali; Jonathan S Schildcrout; Rosette Chakkalakal. Evaluation of a Workplace Diabetes Prevention Program Delivered via Distance Learning: A Qualitative Study [J]. *Health education & behavior: the official publication of the Society for Public Health Education*. 2024. <https://doi.org/10.1177/10901981241285433>
- [7] Zhang Yanwu, Chen Lijun, Chen Xuemei. Application of the Flash technique in the virtual laboratory of human anatomy [J]. *Modern Educational Equipment in China*, 2007, 6: 13-14. (In Chinese).
- [8] Yuksel Aliev; Galina Ivanova; Adriana Borodzhieva. Design and Research of a Virtual Laboratory for Coding Theory [J]. *Applied Sciences*. 2024, 14(20): 9546-9546. <https://doi.org/10.3390/APP14209546>
- [9] Chitra Ebenezer; Mubin Siti Azreena; Nadarajah Vishna Devi; Se Wong Pei; Sow Chew Fei; Er Hui Meng; Mitra Nilesh Kumar; Thiruchelvam Vinesh; Davamani Fabian. A 3-D interactive microbiology laboratory via virtual reality for enhancing practical skills [J]. *Scientific Reports*. 2024, 14(1): 12809-12809. <https://doi.org/10.1038/S41598-024-63601-Y>
- [10] Michelle Deschênes; Lucie Dionne; Séverine Parent. Supporting digital competency development for vocational education student teachers in distance education [J]. *Frontiers in Education*. 2024, 14(1): 1452445- 1452445 <https://doi.org/10.3389/FEDUC.2024.1452445>
- [11] Henrique Simas; Raffaele Di Gregorio; Roberto Simoni. Design of a Fast Robotic Total Station Through Ad Hoc Virtual Experiments and Its Digital Twin† [J]. *Electronics*. Volume 13, Issue 21. 2024. PP 4248-4248. <https://doi.org/10.3390/ELECTRONICS13214248>
- [12] Ziguang Zhao; Xiaobing Yu; Yansong Shen. Effects and mechanism of using ferro-coke in an ironmaking blast furnace—A virtual experiment [J]. *Fuel*. Volume 382, Issue PA. 2025. PP 133726-133726. <https://doi.org/10.1016/J.FUEL.2024.133726>
- [13] Hiwot Bazie; Bekele Lemma; Anteneh Workneh; Ashebir Estifanos. The Effect of Virtual Laboratories on the Academic Achievement of Undergraduate Chemistry Students: Quasi-Experimental Study [J]. *JMIR formative research*. Volume 8, Issue. 2024. PP e64476. <https://doi.org/10.2196/64476>
- [14] Brian Shambare; Thuthukile Jita. Understanding science teachers' TPACK for virtual lab adoption in rural schools in South Africa: a mixed-methods approach [J]. *Frontiers in Education*. Volume 9, Issue. 2024. PP 1426451-1426451. <https://doi.org/10.3389/FEDUC.2024.1426451>
- [15] Aliya Karmanova; Galiya Madybekova; Nusret Kavak; Bayan Ualikhanova; Assel Zharylkassyn; Zhanat Umarova. Developing the Professional Competence of Future Chemistry Teachers through Digital Technologies: A Case Study of Kazakhstan [J]. *JMIR formative research*. Volume 8, Issue. 2024. PP e64476. <https://doi.org/10.2196/64476>

Research Fields

Ma Shengjian: Molecular Biology, Biological Education, Plants, Gene, Polysccarides

Huang Jialing: Molecular Biology, Biological Education, Plants, Gene, Teaching

He Jintu: Molecular Biology, Biological Education, Plants, Gene, Teaching