Research on the teaching mode of university virtual laboratory based on component technology

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Abstract: In order to overcome the problems of low flexibility, low efficiency and non-reusability of laboratory teaching mode, a research method of university virtual laboratory teaching mode based on component technology is proposed. This method is composed of platform architecture module, platform operation module, routine project detection module and platform component module. Through the platform operation module scheduling module components to complete the experimental process; the components needed in the experimental process are detected, so that students can get more accurate experimental process and experimental results. By extracting the internal information of bean component, controlling and managing the dynamic results of the component after execution; using the component technology in swing graphics toolkit to realise the experiment process and result visualisation. The experimental results show that it can improve the utilisation rate of students' spare time, and the experimental practice ability can be improved by more than 15 points.

Keywords: component technology; virtual laboratory; teaching mode; software development; visualisation.

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1 Introduction

Virtual laboratory is first proposed in the USA in the late 1980s, which mainly presents the virtual laboratory environment of computer networking (Zhao, 2017). Virtual reality (VR) technology is widely used in the field of education. It has the characteristics of high development and proportion interaction. It can easily cross the barriers of time and space and expand the scope of ideological education. In essence, virtual laboratory is an electronic and networked integrated environment for scientific research, which gathers a variety of tools and technologies. Researchers describe the virtual lab as a ‘research centre without walls’. Under the support of distributed network environment, no matter where the user is, the virtual laboratory can carry out experimental research together, and they can communicate with each other, use instruments, realise the sharing of resources and data, they also can store the obtained experimental results, edit the experimental reports, etc. Compared with the traditional face-to-face experimental teaching mode, virtual laboratory teaching mode has the advantages of high efficiency, low cost, safety and unlimited convenience (Hong, 2018). Through virtual laboratory, users can only learn from experiments without the limitation of time and place in the traditional face-to-face experimental teaching mode, omit a large number of simple and repeated experimental processes, and focus on the phenomenon and law of imaging of experimental objects in the experimental process, so as to improve the efficiency of experimental research. The virtual laboratory can greatly alleviate the high cost of scientific research and the lack of research funds. Therefore, the existing scientific instruments can improve the research efficiency (Wang et al., 2018). However, due to the influence of equipment volume, equipment funds and experimental time, some experimental courses can only be analysed theoretically and cannot be practiced, which have a negative impact on the cultivation of talents in universities.

In the traditional face-to-face experimental teaching mode, chemical reactions are easy to occur among various experimental samples in the experimental process, which seriously threaten the safety of users. Zhou et al. (2017) takes the experiment of Chinese medicine processing as an example, combines modern information technology with traditional Chinese medicine, builds a virtual laboratory based on Android mobile platform, conducts case analysis of ‘virtual and real’ experimental teaching mode, and carries out effectiveness research. The practice shows that the integrated teaching mode of virtual experiment and traditional experiment teaching cannot only improve the teaching effect, but also reduce the dependence on laboratory resources and improve the utilisation rate of existing resources. However, the experiment teaching mode is not flexible. In Ma et al. (2018), aiming at the coordinate transformation of robotics, the relationships among Euler angle, RPY angle, rotation axis/angle, unit quaternion and homogeneous transformation matrix are shown by experiments in virtual environment, and the spatial significance of DH matrix is explained by virtual means. It can make the teaching process more reasonable. However, the reusability of the teaching mode of the virtual laboratory is poor. Fang et al. (2018), in order to adapt to the reform and development of national education system, improve the quality of experimental teaching, reduce the cost and risk of teaching, try to apply VR as a high-tech to teaching, and build a virtual training system with strong interaction, immersion and imagination. However, the cost of the virtual laboratory teaching mode is high.

Based on the above problems, this paper puts forward the research method of virtual laboratory teaching mode based on component technology. The innovation of this paper is to use component technology to solve the technical problems in virtual experiment teaching mode. Through the combination of the software development mode of component technology and the design idea of object-oriented program, the virtual laboratory software development system which encapsulates the development of experimental instruments gradually is widely used.

2 Teaching mode of virtual laboratory in universities

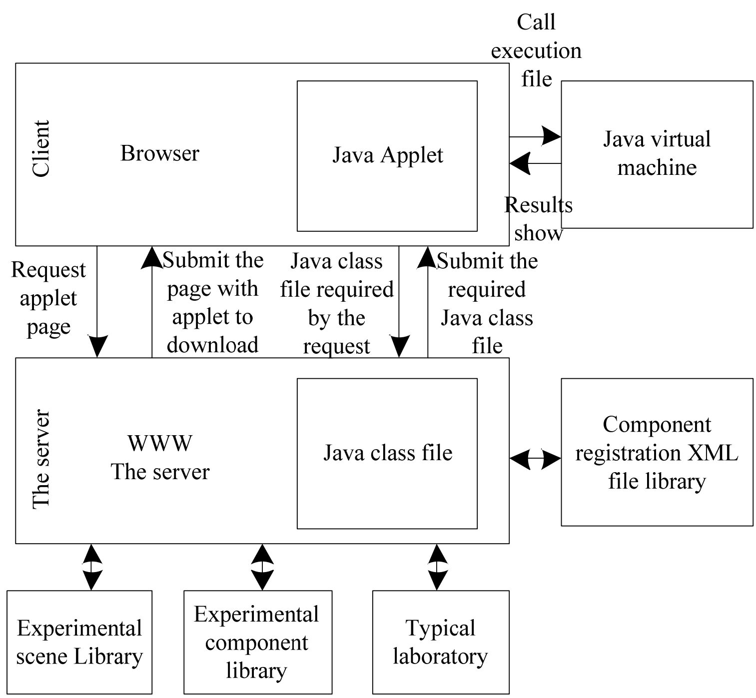
Software development based on component technology has the characteristics of flexibility, high efficiency, reusability and maintainability, which is the main development direction of software production engineering. From the perspective of university education, improving the practice and innovation ability of university students is the main goal of virtual laboratory research and development (Xue, 2019). Therefore, it is of strategic significance for the development of practical teaching to study the teaching mode of virtual laboratory in universities by building a virtual laboratory platform based on component technology.

2.1 The architecture of university virtual laboratory

According to the requirements of university virtual laboratory, considering human-computer interaction function, component library expansion performance and software reuse performance and other factors (Wei et al., 2018; Burkart and Kolar, 2017; Fan et al., 2017), a university virtual laboratory platform based on component technology is constructed. In this platform, we use the Java Bean technology of Sun Company to design the component structure and encapsulate the virtual instruments in each component structure. The essence of each component is a separate computing structure, which contains its own internal environment and a set of operations that can achieve detailed functions (Yang et al., 2017). According to the set interaction protocol and interface coordination standard, components with different functions and appropriate granularity are reused. These components are constructed into different application modules through flexible collocation, and different virtual experiments are implemented.

The teaching mode of university virtual laboratory based on component technology is B/S mode, which is mainly divided into two parts of client and server (Wang et al., 2017), as shown in Figure 1.

Figure 1 Structure of teaching mode system of university virtual laboratory based on component technology



In Figure 1, the client is implemented by Java applet. The web server contains the set Java class file, component library file and file library. The main function of XML file in the file library is component registration configuration.

The client sends the command to download the applet page to the server through the browser. The browser supports Java virtual machine. The server executes the command after receiving the download command and sends the downloaded page to the client. The user sets the experiment process after running the applet page through the client, and at the same time, sends the download command of the instrument components encapsulated in the Java class file to the server. After the server receives the command and executes the command, the client downloads these Java class files to the local system through the Java virtual machine, and constructs the Java class file according to the set experiment process.

The experimental scene library, experimental component library and the stored typical experimental library constitute the server side, which executes the download command sent by the client through the World Wide Web, and feeds back the download result to the client. During the running process of the server, the components are registered in the XML library file, and the XML library file is parsed successfully. At the same time, the gradual file reading of the experiment is performed.

2.2 Function modules of virtual laboratory platform in universities

2.2.1 Platform operation module design

The main function of the platform running module is to execute the experiment process set by the user. After the user starts the experiment, the platform operation module identifies the experiment process set by the user, and generates a directed acyclic graph according to this process (Hao et al., 2017; Guan, 2018; Jian et al., 2018). The directed acyclic graph takes the algorithm components as nodes, and the lines between different components as edges. According to the correlation between the data of each component, the topological sequence of the virtual experiment process is determined. At the same time, the parallel relationship between components is analysed. For the components that can operate in parallel, a single thread is needed to implement the operation. There is a management thread in the platform running module, which is mainly responsible for the management of all the working threads used for calculation (Rana et al., 2017), including the parallel relationship between all the running threads and the execution of the user's stop command. The running flow of virtual experiment is shown in Figure 2.

2.2.2 Detection module of general items

In the process of students' experiment in virtual laboratory, parameter setting is the most critical (Zeng and Fu, 2017). University students usually think that parameter knowledge is complex and abstract. This problem is solved simply in the virtual laboratory. The conventional project detection module inputs the parameters to be detected into each virtual instrument and stores them in the form of human-computer interaction by simulating the analysis and monitoring methods of different reaction types such as self-generation timing method and continuous detection method. At the same time, the conventional item detection module can also be used to detect the experiment content, experiment process, required instruments and reagents independently designed by users. Figure 3 describes the block diagram of conventional project detection module.

Figure 2 Operation flow of system operation module

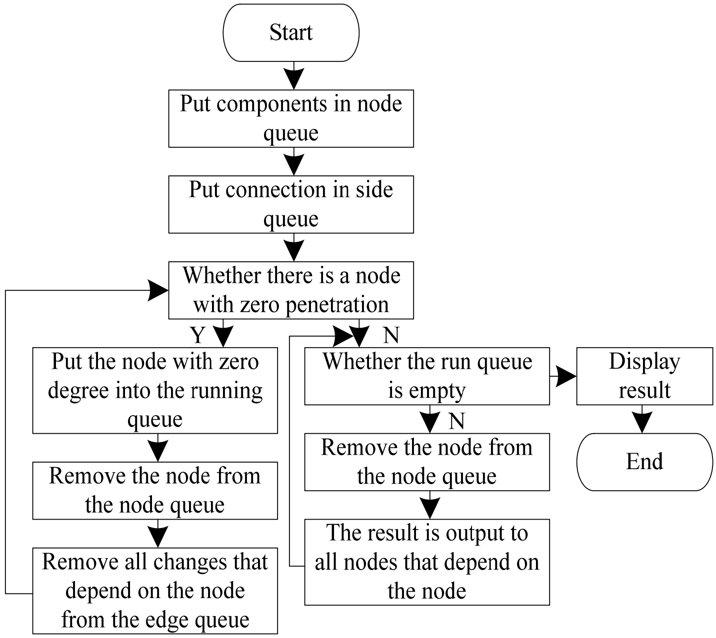
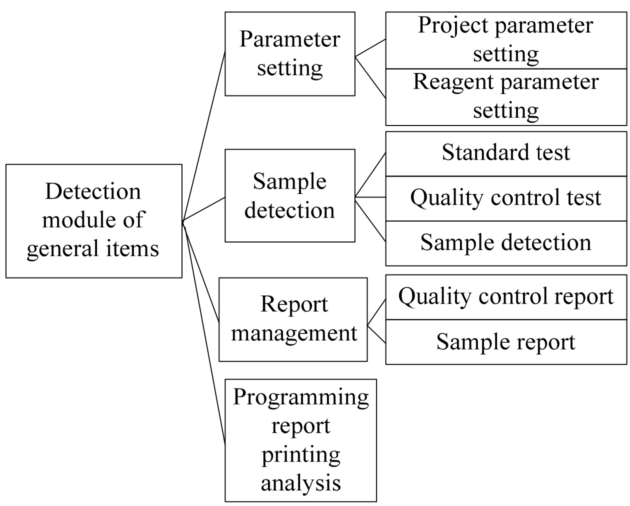


Figure 3 Block diagram of routine item detection module

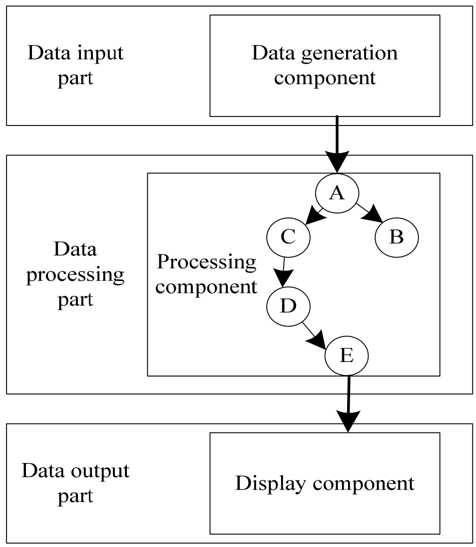


For example, students can use the routine item detection module to detect alkaline phosphatase in the process of experiment with alkaline phosphatase, apply alkaline phosphatase theory in the selection of reaction type, reaction wavelength and reaction reading point, and determine the ratio pre-reaction delay of reagent/sample according to the parameters of the kit. At the same time, in some important experimental process, through the setting of the magnifying glass and other functions, students can better understand the experimental process and obtain more accurate experimental results.

2.2.3 Platform component module

According to the operation sequence of the experimental process, the platform component module can be divided into three parts (Ding and Lv, 2017), as shown in Figure 4.

Figure 4 Scheduling process of experimental operation



The main function of the data input part is to provide the data source that needs to be used in the experiment. The user can generate the data source text by manual input or file transfer, which is the part of generating data in the experiment. The data input part generates the data and then transmits it to the data processing part. After the data processing part obtains the data, it carries out topological sorting on different algorithm components according to the sequence of the experimental process, obtains the linear sequence of different components, and executes different algorithm components one by one according to the sequence. As the management and control centre of the component, the main function of the data processing part is to manage and control the operation of the component, execute the experimental process set by the user, and send the experimental results to the data output part (Falode and Gambari, 2017). The display components contained in the data output layer output the experimental results in the form of text or table for users to view.

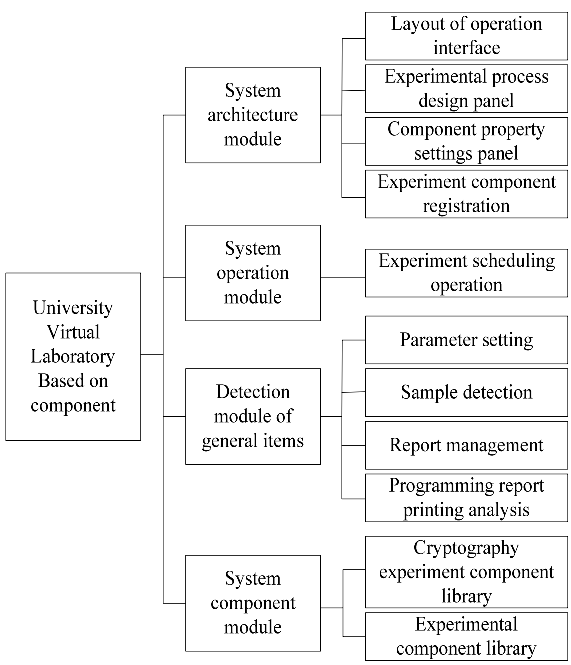
3 Research on the teaching mode of university virtual laboratory based on component technology

Component technology is the most popular software system integration method, which is the basis of distributed computing and web services. Software components in network applications, also known as middleware, each component will provide some standard and simple application interfaces, allowing users to set and adjust parameters and properties. Users can combine multiple components from different sources to form a complex (large-scale) application that meets the actual needs (and is relatively cheap). The main characteristics of components different from general software are reusability (common/general), customisation (setting parameters and properties), self-inclusiveness (modules are relatively independent, functions are relatively complete) and interoperability (multiple components can work together). It is easy to use visual tools to realise component integration, which is also an important advantage of component technology.

3.1 Component packaging of virtual instrument

In order to detect the components needed in the experiment and make the students get more accurate experiment process and results, the platform has been based on. As shown in Figure 5, the university virtual laboratory platform based on component technology is mainly composed of platform architecture module, platform operation module, routine project detection module and platform component module. The function of platform architecture module is to design platform interface, set experiment process, set experiment component attribute and register experiment component. As the core module of the platform, the main function of the platform operation module is to schedule the process of setting-up each component to complete the experiment during the experiment. The main function of the routine project detection module is to detect the components needed in the experiment process, so that students can get more accurate experimental process and results. The platform component module contains a typical experimental component library of cryptography.

Figure 5 Functional structure of virtual laboratory platform in universities



Component is a simple encapsulation of data and methods (Yang et al., 2018). In the process state of university virtual laboratory platform, analytical model files are needed to determine data variables. The interactive control of the platform, the loading of the experimental environment and the parameter setting of the virtual instrument all determine the data from the established data model to realise their own functions (Roy et al., 2017). By parsing the XML template file, the data source is generated to encapsulate the variables. During the experiment, the basic information of the model, such as name, location, size, etc., is saved in XML, which is controlled centrally and easy to transfer.

In essence, the encapsulation experimental method is to encapsulate the logic function of virtual instrument. There are a large number of virtual instruments of different types and functions in the virtual laboratory platform of universities. Therefore, when encapsulating the release method, it is necessary to prevent other gradual anomalies caused by the single class in the component according to the common closure standard. The component encapsulation includes four steps: initialisation, event binding, rendering and clearing.

1 Initialisation: The initialisation process includes creating variable names, defining DOM nodes, importing XML templates to parse data and related classes.

2 Event binding: In the working state of university virtual laboratory, users only consider using external hardware such as mouse to operate virtual experimental instrument, while event binding mainly focuses on the binding between event and HTML element and how to handle after event triggering (Hämäläinen et al., 2018). Dynamic binding is used to bind multiple events on a thread node that can be paralleled, and operations are performed in sequence during event triggering.

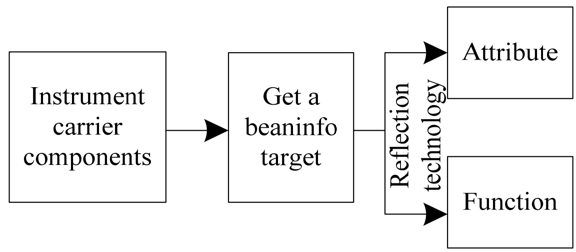
3 Rendering: Render the data in the script file in the HTML page. In order to improve the rendering speed and experiment efficiency, it is necessary to reduce the number of network cycles and the size of important resources in the process of rendering HTML pages. In order to prevent browser from waiting for CSSOM to terminate DOM construction due to browser parsing blocking, JavaScript script file is executed asynchronously.

4 Clearing: Clear useless objects and release memory.

3.2 Extract internal information of bean components

During the operation of the platform, it is necessary to introspect the process of extracting the internal information of bean components (Nolen and Koretsky, 2018). In the teaching mode of university virtual laboratory based on component, each component is developed in the form of java bean, and the process of component generation is to encapsulate it into the object of platform custom class instrument carrier. Conditions based on this component are only visible internally. In the working state of virtual laboratory platform, how to obtain the internal information of Java Bean component, choose the function method described by it, and control and manage the dynamic results of the component after execution are the problems to be considered in the construction process of university virtual laboratory based on component technology. The process of extracting the internal information of bean components is shown in Figure 6.

Figure 6 Internal information process of bean component



The grade target defined by the instrument carrier class uses the static method of the introvert, obtain Beaninfo(), to import the grade target in this method, to perform a comprehensive search on it, and to feed back the Beaninfo target covering all the information. As the parent class of the class target, the main function of StopGrade is to prompt the introspection to stop at the parent class of the grade target (Wu and Qiu, 2018).

The property arrays defined in this class are obtained by the obtainProperty Specifier() method of the Beaninfo target. The functions used to write and read property values are obtained by using the obtainWriteMethod() and obtainReadMethod() respectively for each property specifier in this class to get the property values of the grade target. The obtained property values are all method targets, and iIntroduce() completes the introspection of component property parameter correction in the previous section. In order to get the methods in the grade target, the array of methods defined in the subclass can be obtained by the obtainMethodSpecifier() method of the Beaninfo target, the method target relative to each MethodSpecifier can be obtained by using the obtainMethod(), the behaviour method defined by the component can be implemented by using the Introduce() method, the data processing can be implemented, and the obtained results can be sent to the lower level components.

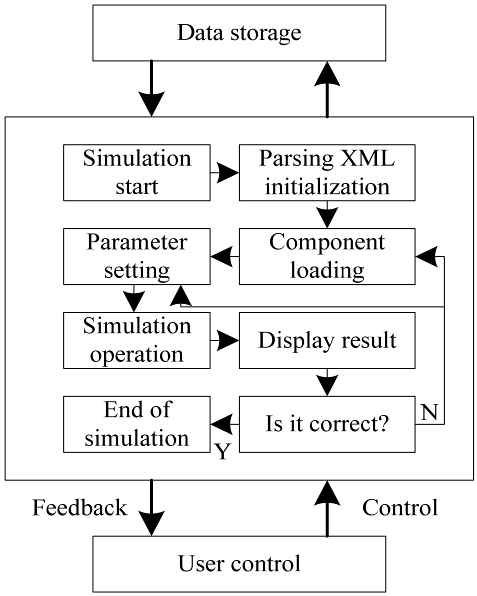
By introducing the static method of introspection and the reflection mechanism of dynamically determining class information provided by bean component into the above process, bean component information can be extracted enough to ensure the timely and effective acquisition of component information in the process of virtual laboratory work, which plays a key role in the construction of university virtual laboratory platform.

3.3 Visualisation of experimental process

All the methods in the university virtual laboratory platform are gradually described in the form of rectangular box (Çelik and Pektaş, 2017), the upper and lower sides of the rectangular box are input and output pins respectively, which can be realised by the drawRectanglet method of the mapping class of swing.

In the experiment process of university virtual laboratory platform, the rectangular frame describing the method component also includes: selecting and moving, gradually completing the specified method function according to the user set method, collecting and outputting pin value and other behaviours. The experiment flow of virtual laboratory platform is shown in Figure 7.

Figure 7 Simulation flowchart



4 Experiment

4.1 Experimental motivation and scheme

In order to test the teaching effect of the method in this paper, according to the background login time interface shown in Figure 8, it is calculated that within half a year of practical learning by the method in this paper and the methods in Zhou et al. (2017), Ma et al. (2018) and Fang et al. (2018), the location and login time of different students landing on the virtual laboratory platform. Half a year later, 200 students participated in the study were tested for practical ability, and ten students were randomly selected to evaluate their experimental practical ability using this method and literature method through teacher rating method. The results of background login time interface are as shown in Figure 8.

The detailed process of virtual laboratory platform experiment simulation is as follows:

1 Initialisation: Analyse the XML template data file, load the components needed in the experiment process according to the parameters, including instruments and methods; select the laboratory scene, and render the initial information of the scene using the components, as shown in Figure 9. The panorama of the laboratory can be obtained by roaming.

2 Download the virtual instrument and reagent components: According to the set experiment process, the user downloads the virtual instrument and reagent components to be used in the experiment, as shown in Figure 10. Using a web browser to analyse the Java script information, the user presents the coordinates,

dimensions and angles of the virtual instrument in the page. The user corrects the virtual instrument position through external hardware.

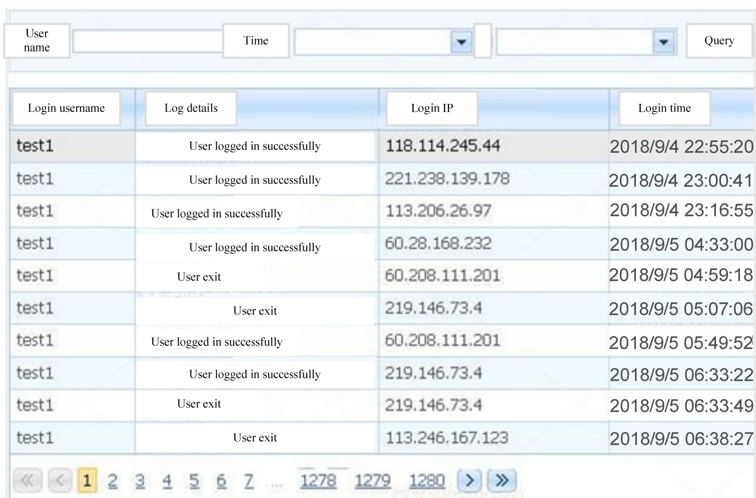
3 Set parameters: The user sets the experiment parameters according to the experiment purpose, as shown in Figure 11.

4 Experimental simulation: After confirming that the parameters are set correctly, carry out the experimental simulation, as shown in Figure 12.

5 Display the experimental results: The experimental results are presented dynamically, and the errors in the experimental process are prompted.

6 Save: During the experiment, the user can store the experiment information at any time to prevent the experiment from being unable to be completed due to unexpected circumstances.

Figure 8 Background login time interface (see online version for colours)



Login username	Log details	Login IP	Login time
test1	User logged in successfully	118.114.245.44	2018/9/4 22:55:20
test1	User logged in successfully	221.238.139.178	2018/9/4 23:00:41
test1	User logged in successfully	113.206.26.97	2018/9/4 23:16:55
test1	User logged in successfully	60.28.168.232	2018/9/5 04:33:00
test1	User exit	60.208.111.201	2018/9/5 04:59:18
test1	User exit	219.146.73.4	2018/9/5 05:07:06
test1	User logged in successfully	60.208.111.201	2018/9/5 05:49:52
test1	User logged in successfully	219.146.73.4	2018/9/5 06:33:22
test1	User exit	219.146.73.4	2018/9/5 06:33:49
test1	User exit	113.246.167.123	2018/9/5 06:38:27

Figure 9 Experimental scenario

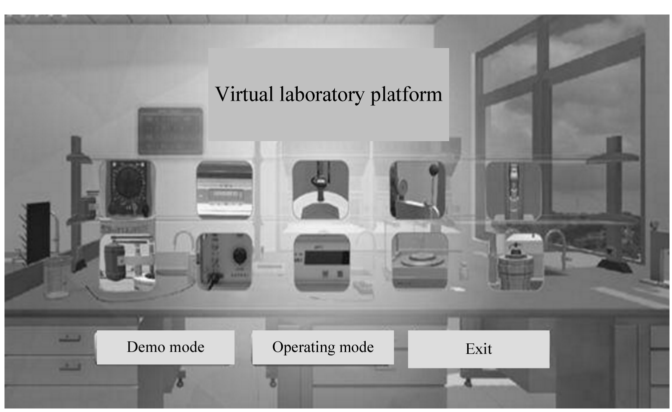


Figure 10 Instrument and reagent selection

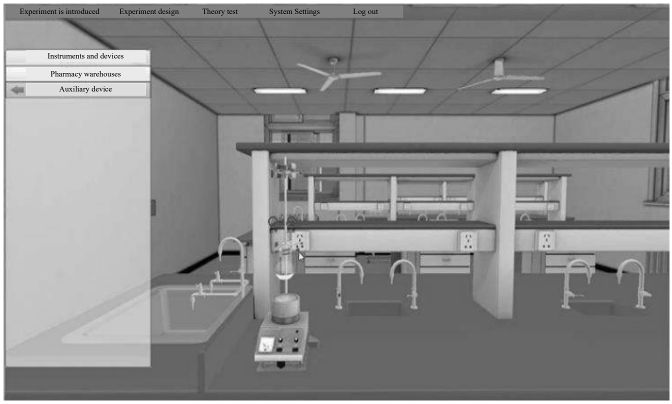


Figure 11 Router parameter setting

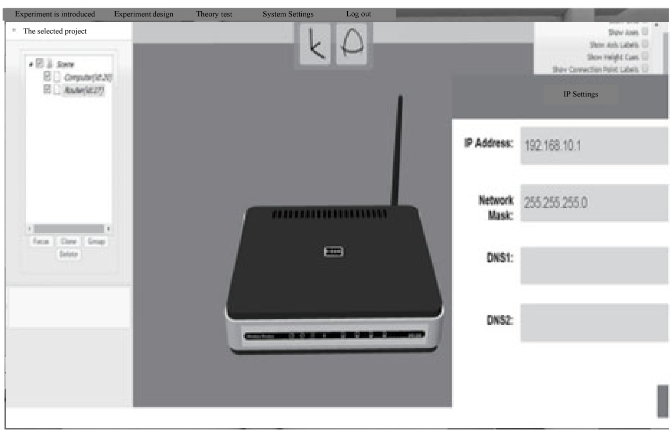


Figure 12 Experimental simulation process

4.2 *Experimental index*

1 Statistics of login place and login time

Half a year later, 200 students participated in the study were tested for practical ability, and their experimental practical ability using the methods of this paper and literature was evaluated by teacher rating method.

2 Comparison of experimental practice ability

$$R_i = \frac{1}{k}\sum_{i=1}^{k}\left(T_{i,j} \times \omega_1 + d_i \times \omega_2 + e_i \times \omega_3 + a_i \times \omega_4\right) \tag{1}$$

In the above formula, i refers to the students who participate in online learning (including experimental exercises), j refers to the teachers who participate in online teaching (including experimental guidance), and $T_{i,j}$ is 0 refers to the form of students' autonomous learning, forming an online teaching community. ω_1, ω_2, ω_3 and ω_4 represent the weight of online learning (each student has different weights according to different situations, but the total is 100), K represents the number of students participating in online learning (including experimental exercises), and R_i represents the learning effect (assessment score) of each student (individual).

4.3 *Teaching effectiveness*

From Table 1, it can be seen that after the practical learning with this method, 7% of the 200 university students choose to log in the virtual laboratory platform outside the school, 24% of the students choose to log in the virtual laboratory platform inside the school, and 69% of the students log in the virtual laboratory platform in other areas of the school. After the practical study of literature review method, the vast majority of students still choose to log in to the virtual experiment platform only in the laboratory of the school, and the learning place is restricted greatly.

Table 1 Statistics of login places

Place of entry	*Proportion of logins / %*			
	This method	*Zhou et al. (2017) method*	*Ma et al. (2018) method*	*Fang et al. (2018) method*
Outside school	7	5	4	5
In school laboratory	24	89	91	93
Other areas of the school	69	6	5	2

According to Table 2, the time period for university students to log in to the virtual laboratory platform is divided. The highest number of students is 10:00–14:00, 16:00–22:00, and the number of students to log in is more than 50%. The experimental data show that the location and time of students' login are relatively wide, and the learning location is no longer limited in the laboratory. After using literature review method to practice learning, the login time is still concentrated in a certain period of time, and the learning time is limited. Therefore, after using the method in this paper, it can improve the utilisation rate of students' spare time to the greatest extent, which is conducive to improving students' experimental practice ability.

Table 2 Statistics of login time

Login time	*Number of logins / person*			
	This method	*Zhou et al. (2017) method*	*Ma et al. (2018) method*	*Fang et al. (2018) method*
06:00–11:00	52	10	5	10
10:00–14:00	136	2	6	8
14:00–16:00	48	6	4	6
16:00–22:00	109	9	168	171
22:00–24:00	49	172	11	6
24:00–06:00	12	10	15	16

Table 3 shows the comparison of students' experimental practice ability. It can be seen from the analysis of its implementation that due to the differences of students' own abilities, the improvement ranges of students' experimental practice ability in this method are different. However, compared with the literature review method, most students' experimental practice ability is improved by more than 15 points, which indicates that this method can effectively improve students' experimental practice ability.

Table 3 Comparison of experimental practice ability

Student number	*This method / score*	*Zhou et al. (2017) method / score*	*Ma et al. (2018) method / score*	*Fang et al. (2018) method / score*
1	86	66	70	78
2	91	82	81	90
3	93	80	87	86
4	84	77	73	72
5	84	73	79	71
6	80	71	61	72
7	97	79	72	80
8	81	74	73	76
9	84	78	74	69
10	85	72	77	78

5 Conclusions

This paper puts forward the research method of teaching mode of university virtual laboratory based on component technology. This method constructs the platform of university virtual laboratory based on component technology, which is composed of platform architecture module, platform operation module, routine project detection module and platform component module. Through each component in the platform operation module scheduling module, the experiment process is completed and the internal information of bean component is extracted control and manage the dynamic results of the component after implementation; use the component technology in the swing graphics toolkit to realise the visualisation of the experimental process and results.

The experimental results show that most of the students' after-school utilisation rate has been improved, and the experimental practice ability has been improved by more than 15 points, which provides a new idea for the current practical teaching reform. Through the improvement of the experimental teaching mode, college students can combine the theoretical knowledge with the practice to the greatest extent, and provide new ideas for the current experimental practice teaching reform.

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