The Development and Application of Virtual Experiment Platform for Function Parameter Passing

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***Abstract*—As computer programs run in the highly complex systems of hierarchical software and hardware, it is difficult to be visually observed, the problem of function parameter passing has become a pain point for teachers and students. There are four ways to pass parameters, and no programming language can support all the four ways. To meet the needs of different learners, an online virtual experiment platform of parameter passing is developed, where the experiments of four methods parameter passing can be carried out. In addition, the experiments could be done by a mobile phone, which the space-time limit of learning is broken. In virtual simulation module, the dynamic changes of computer memory could be simulated and displayed when the function pseudo-code is running, so that the parameter passing process becomes intuitive, and it is easy for students to understand the working mechanism of function parameter passing. Finally, the teaching goal is achieved by the joint action of the other modules, such as basic training, extended improvement and test enhancement, etc. The results of practice show that the enthusiasm and initiative of students are improved, and it has obvious results in assisting students to master the knowledge of function parameter passing.**

Keywords—virtual labs, function parameter passing, learning management systems (LMS), Active learning

I. INTRODUCTION

Nowadays, there are a large number of people learning computer programming languages in the era of algorithms， and many beginners are discouraged from computer programming due to the pain point of function parameter passing[1-3]. To acquire possess algorithmic literacy, more and more internet users are actively learning computer programming. In addition, most science and technology majors offer programming courses, and some majors even start multiple programming courses. As the programs run in the highly complex systems of hierarchical software and hardware, and their execution process is invisible. It difficult to understand the internal processes and principles of program code execution for beginners, which poses a great challenge to their learning [3, 4]. Thus, the problem of parameters passing has become a pain point for students, dampening their enthusiasm.

The problem of function parameters passing is also difficult in teaching and it also is a pain point for teacher. In the teaching process, the corresponding chart is generally used to show the internal state of computer memory by the teachers with rich teaching experience. As the chart is static, it is difficult to describe the process of parameter passing clearly by the method of drawing explanation. In addition, the program logic is usually more complex, and the same function would have multiple types of parameters, a little change in program logic would lead to a huge difference in operation, resulting in a very limited experimental teaching effect [6].

A. Motivation

As a new educational productivity, the virtual simulation technology provides an effective means for the construction of new intelligent teaching [7,8]. If the dynamic changes of computer memory could be simulated and displayed by virtual simulation technology, while the process of parameters are passing, it is a great significance for the teaching and learning of programming languages. There are total four ways to pass parameters in the existing languages, such as "pass value", "pass address", "get the result" and "pass name". But there is no language that can support the four ways at the same time. Therefore, to meet the learning needs of different programming languages, an experiment teaching system of parameter passing would be constructed by virtual simulation technology, in which the experiments of four kinds parameter passing can be carried out. The system would be helpful to solve the pain points that have long troubled teachers and students in the course of computer programming. We believe that is a very meaningful and worthwhile thing to do.

B. Contributions

In this paper, we mainly solve the problem of function parameter passing in computer programming course, which is the pain point for teachers and students. Our contributions include the following.

First, an online virtual experiment platform for function parameter passing is designed and constructed by Html5, Vue.js and SVG, etc. It can carry out four kinds of parameter transfer experiments, and the dynamic changes of computer memory can be simulated and displayed, while the process of parameters are passing.

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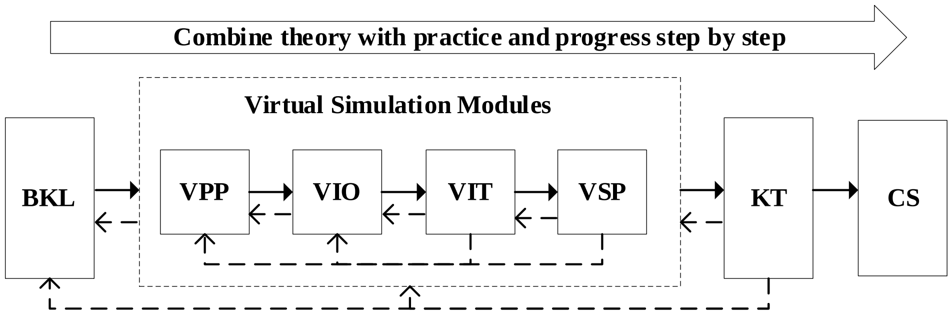

Fig. 1. Experimental teaching process design

The second, in teaching practice, the effectiveness of the experimental platform is verified. The results of practice show that the enthusiasm and initiative of students are significantly improved, and it has obvious results in assisting students to master the knowledge of function parameter passing.

The rest of the paper is organized as follows. Section II introduces virtual experiment platform development. Section III presents the practice and effect of experimental teaching. Section IV gives conclusions and directions for future work.

II. VIRTUAL EXPERIMENT PLATFORM DEVELOPMENT

A. *Experimental Teaching Process Design*

The concept of OBE (Results-based Education) is widely used in curriculum design because of its advanced and high efficiency[9,10]. In order to continuously improve the learning effect and satisfaction of students, the experimental teaching process of function parameter passing is designed and constructed based on OBE concept.

Firstly, the experimental teaching objectives of function parameter passing firstly are described from three dimensions: "Knowledge", "Ability", "Quality", and ensure that the objectives can be implemented, quantifiable, measurable. Then, based on the experimental teaching goal, the teaching process is divided into "Basic Knowledge Learning" (i.e., *BKL*), "Visual Parameters Passing" (i.e., *VPP*), "Visual Interactive Operation" (i.e., *VIO*), "Visual Interactive Test" (i.e., *VIT*), "Visual Self-Programming Practice" (i.e., *VSP*), "Knowledge Testing" (i.e., *KT*) and "Communication and Summary" (i.e., *CS*). Among them, the *VPP*, *VIO*, *VIT* and *VSP* are virtual simulation and experiment exercise modules. The Experimental teaching process of function parameter passing is shown in Fig.1.

In the modules of *VIT*, *VSP* and *KT*, students self-evaluate their learning results. Based on the self-assessment results, students can choose whether to return to the previous corresponding module to learn repeatedly, or enter a new module to complete the corresponding task. Based on the tasks of the *KT* and *CS*, teachers evaluate the learning effect of students and make continuous to improvement.

In *BKL* module, the basic knowledge of function parameter passing is presented by the method of fun question-and-answer dialogues with cartoon characters. In the way, the students are attracted to learn knowledge actively.

In the virtual simulation and experiment exercise modules, students understand and master the basic knowledge of function parameter passing. In the *VPP*, it is visually show how the values of various real parameter variables change in memory over the life of a function call. In the *VIO*, while the virtual simulation software is operated by student to simulate the interactive step-by-step running of pseudocode, such as the storage of function parameters, the interaction process of real parameters, the characteristics, operation and results of different types of parameters, can be observed from different angles. At the same time, the built-in principles of function parameter passing are understood by the observing. In "Visual Interactive Operation", after parameter values and estimated values being inputted, students operate virtual simulation software to run pseudo code in an interactive visual way to check the correctness of their estimated results. In *VSP*, the running process of the program written by the students is dynamically displayed in a visual way.

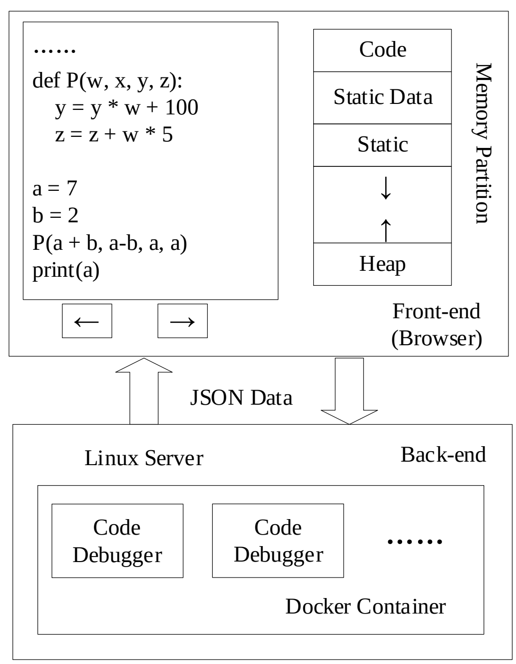

Fig. 2. Core-element simulation design

The *KT* module aims to test the achievement of experimental teaching objectives. The test questions are closely related to the teaching objectives and focus on the ability of students. Students who fail the test are required to return to the previous model to study again.

The *CS* module aims to train students' ability of literature review, academic problem summarization. Students combine freely in groups of 3-5. The related problems of function parameter passing are discussed in small groups, and the discussion record and the summary report are submitted. The problems discussed are: What is the difference and relation between shape and local variables; What operations a parameter can perform, how these operations affect the argument and the storage space to which the argument refers, and so on.

B. Design and Implementation of Core Simulation Elements

As the Python language has many advantages and it has a large user group, in the way of pseudo-code simulation running in Python language, it shows the dynamic change process of the real parameter value in the computer memory when the parameters of the above four kinds parameter are passed. It makes the parameter passing process intuitive. In the virtual simulation and experiment exercise modules of platform, the core simulation elements mainly are consisted of two parts: the front-end and the back-end, as shown in Fig. 2.

The back-end is built on a Linux server with multiple Docker containers. For each Docker container, there are multiple code debuggers (e.g., *Pysnooper* [11]) installed. The source code sent by the platform user is run independently in the corresponding code debugger, and the debugging information of the program is returned to the front-end requester in JSON format.

The front-end is a visual virtual simulation environment built in the browser. It has two main roles, one is to convert pseudo-code into semantically equivalent Python code and then send it to the server. The second role is to visually draw the variables, values and their relationships in the heap, stack and global data area of the computer memory after each program runs, according to the JSON data debugged by the program.

The internal state of the computer is visually displayed in a highly abstract form, which the invisible internal information of the computer is virtual simulated into a visible state, and students are allowed to interact with it through the program.

The design of the experimental platform includes both the "real" part and the "virtual" part, which has the advantage of combining the virtual and the real. The "real" part is in the back end of the system. By our Python pseudo-code translator developed, the pseudo-code sent by the front end of the platform is equivalent to the Python code, and it is compiled and run, in order to obtain the real information of the computer memory state, such as: variable memory address, value, etc. The "virtual" part is reflected in the front end of the experimental platform, that is, in the browser side. The invisible state of the computer's memory is visualized virtually, which can be evolved dynamically as the program executes. The experimental platform achieves the characteristics of virtual and real combination by the effective coordination of front and back ends.

C. Experimental System Design and Implementation

The architecture of the experimental platform is consisted of three parts: platform front-end, back-end and Web server, as shown in Fig. 3. The experimental process is organized by the above teaching process design. The experimental platform has been developed and deployed in Alibaba Cloud, and the login main page is shown in Fig. 4.

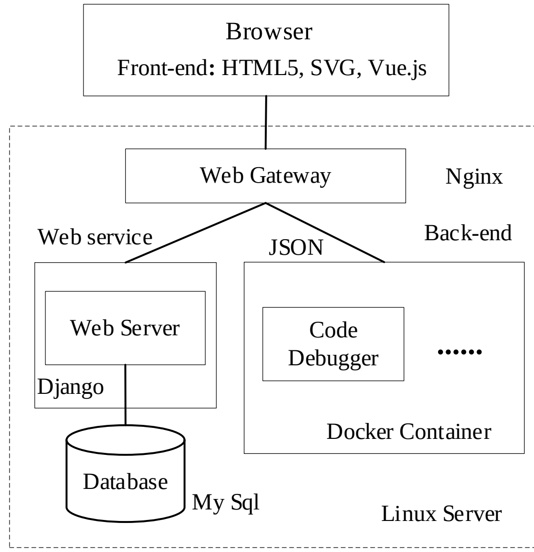

Fig. 3. Experimental platform architecture

The experimental teaching process was designed and organized based on the experimental teaching process. The total learning time of a single experiment was 90 minutes, and the full score of the 19-step interactive operation was 100. Within the total time limit of a single experiment, students can repeat the corresponding interactive operation steps, and can repeat the experimental learning according to their personal circumstances. After logging in the experimental teaching platform, students complete 19 interactive operation steps. For each parameter transfer method there are four interactive operations, and here are 4 types of parameter passing methods, so a total of 16 interactive operations are corresponded. In addition, there are knowledge tests, experimental summaries and extended experiments (free training), a total of 19 steps of interactive operations. For each interactive operation step, reasonable time, goal achievement degree scoring model and step full score are set. According to the student's current step completion, the platform automatically scores and only records the latest score.

Fig. 4. The login main page of the platform

The back-end of the experimental platform developed by Python and running on a Linux-like system, its function is to dynamically create a compilation and running environment for each Python program by calling Docker container to, and obtain detailed information about program operation by the debugger. The information that program is running is edited by the JSON format, and it is returned to the front-end of the platform. The information with JSON format is convenient for writing and machine parsing, and can effectively improve the efficiency of network transmission of information.

The Web server side of the platform developed by Django and MySQL runs on the Linux or Windows environment. Its functions are the user management, experimental process control and coordination of the entire experimental teaching operation, etc.

The front-end of the platform constructed based on the technology of HTML5, JS, Element UI, SVG, etc., runs on the browser. Its functions are user login verification, experimental teaching process management, and human-computer interaction with the user's experimental operation, etc. In addition, the JSON-formatted data is visualized in the front-end accordingly, which is captured from the Web server and the back-end of the platform. For example, to visualize the dynamic effects of running a program.

III. TEACHING PRACTICE AND EFFECT

This section first introduces the design and preparation of teaching reform practice based on the experimental platform, and then introduces the effect of teaching reform practice.

A. Teaching Practice Design

Select Research Object: 123 students majoring in computer science and technology in 2021 were selected as research objects to carry out the experimental teaching reform of function parameter passing based on the experimental platform. In the fifth semester, the teaching research is carried out, and the research object has a certain foundation of high-level language programming.

Research Design: A longitudinal comparative study was used. Based on the knowledge points of four kinds of function parameter transfer methods, three tests were carried out in the school learning platform respectively "Before Explanation" (i.e., *BE*), "After Explanation" (i.e., *AE*) and "After Training" (i.e., *AT*). The three tests have the same test paper difficulty, question type and number of questions. Among them, *BE* refers to the test carried out after the theoretical teaching and before students use the "Basic Knowledge Learning" in the experimental platform to carry out self-learning. The *AE* refers to the test carried out after the "Basic Knowledge Learning" and before students use the "Visual Parameters Passing" in the experimental platform to carry out self-learning. *AT* refers to the test carried out after the "Visual Self-Programming Practice" module. That is, *AT* refers to the test carried out after the virtual simulation and experiment exercise modules of the experimental platform.

Evaluation index: Students' individual scores are composed of two parts: experimental process scores and experimental summary report scores, that is, individual experiment scores = process scores *60% + summary report scores *40%. The individual experimental process scores are automatically assessed by the experimental platform based on the completion of the 19-step interactive operation. Based on the contribution of the individual in the group, the score of individual summary report collectively is assessed by the student group.

B. Teaching practice effect

In the three tests of *BE*, *AE* and *AT*, the ratio of the number of people who answered correctly in the questions of various kinds of parameter passing methods to the total number of people tested was compared, as shown in Fig. 5.

As can be seen from the Fig. 5, it can be seen that the experimental platform has obvious effectiveness in assisting students to master the knowledge of function parameter transfer. For each method of function parameter passing, the number of students who answered the questions correctly in the three tests showed an increasing trend. In other words, for each function parameter passing method, with the advancement of the teaching process in the platform, more and more people have mastered the knowledge of the function parameter passing method.

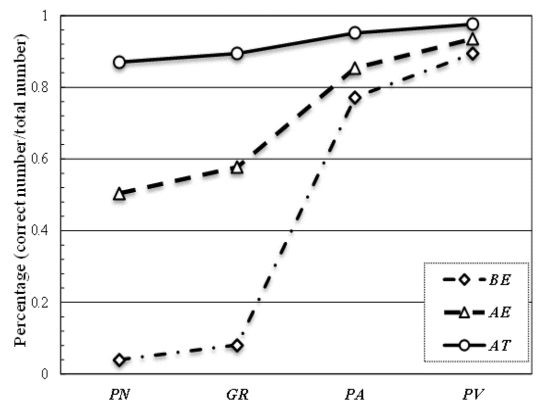

Fig. 5. The results of the three tests

In the *BE* test, the number of students who answered the questions correctly in the "pass value" test was the largest, while the number of students who answered the questions correctly in the " pass address " test was relatively large, and the number of students who got the questions correctly in the "get the result" and "pass name" test was relatively small. It is because the "pass value" and "pass address" methods are more common in programming languages, and the "pass value" method is relatively simple, and it is relatively easy for students to master the knowledge of the two methods of function parameter passing. According to the test results of *AE*, the number of students who answered the questions correctly in the test of the four function parameter transfer methods has significantly increased, which indicates that the learning of the "Basic Knowledge Learning" module is effective. Especially in the *AT* test, the number of students who answered the questions correctly in the test of four function parameter passing methods has greatly increased, which indicates that the learning of the "Visual Parameters Passing" (i.e., *VPP*) , "Visual Interactive Operation" (i.e., *VIO*), "Visual Interactive Test" (i.e., *VIT*) and "Visual Self-Programming Practice" (i.e., *VSP*) modules are effective.

Compared with "pass value" and "pass address", the two methods of function parameter transfer, "get the result" and "pass name", are relatively rare. Before learning the method in the "Basic Knowledge Learning", the answer rate is the lowest in the test, and after the virtual simulation and experiment exercise modules in the platform, most students have mastered the knowledge of these two methods. Although the "pass value" and "pass address" are the more common ways of passing parameters, and the correct rate is higher in the test, there are still many students who do not master the relevant knowledge of the two methods. The intersection between the set of students who gave wrong answers in the third stage test and the set of students who gave wrong answers in the first test is almost equal to the set of students who gave wrong answers in the first test. The analysis of intersecting middle school students found that most of these students are the students who failed every semester, and these students are also the students who should be paid attention to and helped in the follow-up courses.

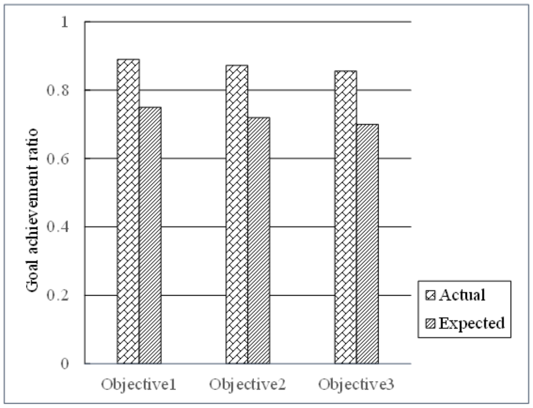

Fig. 6. Experiment teaching goal achievement ratio

The achievement of experimental teaching objectives of function parameter passing is shown in Fig. 6. Before using the platform to carry out the experimental teaching reform, the research group formulated the achievement value of the experimental teaching goal (i.e., Expected) combined based on the traditional teaching experience. After the teaching reform, the actual achievement values of the three teaching objectives of "Knowledge", "Ability" and "Quality" are calculated according to the students' achievements in the experiment process. As can be seen from Fig. 6, the actual achievement degree of these three teaching objectives is higher than the expected achievement degree. It also shows that the experimental teaching platform and teaching method are effective in assisting students to master the knowledge of function parameter transfer.

In addition, after the end of the experimental, a questionnaire survey and a discussion with student representatives were carried out. The results of on-site online voting show that about 95.6% of the students think that the method in this paper can effectively mobilize the enthusiasm and initiative of students to participate in experimental teaching, and can effectively assist students to master the relevant knowledge of four kinds of function parameter transmission. At the symposium of student representatives, the students agreed that the scheme of assigning experimental results was ideal. In particular, the program of assigning individual results to the experimental summary report is more scientific, which effectively mobilizes the enthusiasm and initiative of students to participate in the activities of the exchange and summary stage. Through this activity, students' ability to review literature, summarize academic views and condense scientific problems has been effectively improved. Finally, the interview results of student representatives show that the experimental platform and teaching method have obvious effectiveness in assisting students to master the knowledge of function parameter transfer.

IV. CONCLUSIONS AND FUTURE WORK

The development and application of the experimental teaching platform in this paper have effectively solved the problem of function parameter passing, which has been bothering students and teachers for a long time. Based on virtual simulation technology, the dynamic changes of the computer memory when the pseudo-code is running are simulated and shown, so that the parameter passing process becomes intuitive and easy for students to understand the basic principle and working mechanism of parameter passing. The experimental teaching design based on the OBE concept has aroused the enthusiasm and initiative of students to participate in the experimental teaching, and provided help for the achievement of the experimental teaching objectives.

In the future, on the one hand, the function and performance of the platform will be further improved based on the feedback of students' use experience, and on the other hand, the application promotion of the platform will benefit more students.

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