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# Design of Evaluation System for Digital Education Operational Skill Competition Based on Blockchain

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***Abstract*—By letting students simulate operations and games on a digital education operation system, schools are able to inspect learning achievement and teaching quality. In digital education area, we are able to use blockchain technology to improve competition mode. It's helpful to simplify process, improve efficiency and avoid the problem of opaque and falsification messages. Besides, it can provide unchangeable digital certification of academic achievement. Based on existing research foundation, against features on related users and services, especially the standard and trustful problem in competitions and evaluation mode nowadays, I studied competition mode based on blockchain technology, designed blockchain's application mode and frame, analyzed evaluation criteria and algorithm, designed an operational skill evaluation model, developed an operational skill competition evaluation system based on e-business sandbox and experimented it.**

***Index Terms*—operational skill competition, blockchain, evaluation model, digital education, balanced score card, fuzzy AHP**

## I. Introduction

In the country's strong support for skill competitions, various competitions have been successfully held. The accuracy and authority of the evaluation in the competition process is becoming more and more important. The scientific evaluation is conducive to the healthy development of the competition and enhance the influence of the competition. Meanwhile, as a new application mode of distributed data storage, point-to-point transmission, consensus mechanism, encryption algorithm and other technologies, blockchain has become the focus of attention of governments and international organizations in recent years.

The blockchain has attempted to apply in industries such as financial services, supply chain, medical health, which will bring new opportunities for the development of next-generation information technology. In the field of digital education, blockchain is also looking for suitable application scenarios. For the current situation of operational skill competition, the application of blockchain technology to optimize existing competitions can effectively simplify the competition process and improve competition efficiency, and solve the problem of not public system and opaque information, while providing a credible digital proof of competition results.

This paper focuses on the characteristics of related users and services in the field of digital education, especially the standards and credibility of current competition and evaluation mode, and study a competition mode and operational skill evaluation model based on blockchain technology, and develop an operational skill competition evaluation system based on an e-commerce operation sandbox.

The remainder of this paper is organized as follows: Section II shows the related work; Section III describes the preliminary work. Section IV analyzes the specific situation of the system; Section V describes the evaluation system and model. Section VI explains the system design. Section VII concludes the paper and gives an outlook on future work.

## II. Related Work

### A. "Blockchain +" Education Application

"Sony Global Education" is an educational record storage platform based on blockchain technology, which can store students' educational experiences and provides credible certification. Sharples M et al. [1] proposed a distributed ledger that records not only academic learning activities, but also informal learning activities, such as competition results, internship experience, etc. These learning information can be used as a reference for the employer to examine students' abilities. Yang Xianmin et al. [2] proposed the application mode of blockchain in the field of education through the analysis of financial blockchain, including "distributed storage and recording of trusted learning data", sharing data with other universities or recruitment units, showcasing your academic performance and professional skills.

### B. Skill Competition Mode

Jingzhu Wu [3] pointed out that the current competition has too much assessment contents. It requires a long preparation process for students, which also affects the study of normal courses, making the participation enthusiasm low. Renfang He et al. [4] pointed out that there is a lack of supporting incentives and excessive use of competition skills in the current competition mode. Yafei Yang et al. [5] pointed out that there is a dishonest phenomenon in the current on-line scoring system. Unfair scoring in processing systems becomes an important and challenging issue.

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### C. Evaluation Model

Jackson, TR et al. [6] designed an evaluation tool with ten evaluation items and five open questions, using a single set of post-test methods including retrospective pre-test components to evaluate performance in student competitions and test the student's learning process and results. Shen, Yung Chi et al. [7] proposed an evaluation model applied to enterprise resource planning (ERP) using balanced scorecard dimensions, linguistic variables and non-additive fuzzy integration methods. Shoghli, Alireza et al. [8] proposed the application of balanced scorecard and AHP to evaluate the teaching achievements of academic departments in universities through the questionnaires and semi-structured interviews of academic members and students of the school to obtain data.

### D. Survey Conclusion

At present, blockchain technology has made some attempts in the field of education, which proves the feasibility of the "blockchain+" education mode, but the application scope is limited to the record of students' educational information, and the data-oriented objects are often employers. There is no use at the university level, and the data cannot be reasonably used for evaluation and feedback.

In the skill competition, most of the existing competition modes are in the form of off-line competitions. It is time-consuming and laborious for the organizers and participants. Many competitions have problems such as unscientific competition and unqualified evaluation. On-line competition mode also has problems such as opaque information and untrustworthiness.

In the evaluation of student competitions, a variety of evaluation models have been proposed to judge students' knowledge acquisition and application. For the evaluation of skills of operating enterprises, the evaluation scores are often combined with the balanced scorecard to determine the evaluation indicators.

## III. Preliminary

### A. E-commerce Sandbox

The e-commerce operation game sandbox is a business decision-making sandbox system for e-commerce practice. It simulates and operates an e-commerce platform through multi-round games, aiming at training and inspecting students' basic professional knowledge and practical operational skills. I developed the competition evaluation system based on the operation sandbox.

### B. Trusted Cloud

Trusted Cloud is a third-party public service platform that provides authentic and reliable enterprise and product information, network reputation information and so on. This article combined with Trusted Cloud to provide traceability information for digital education products.

### C. Blockchain

The blockchain was first proposed by Nakamoto in his paper "Bitcoin: A Peer-to-Peer Electronic Cash System" [9], which can be regarded as a special distributed database. Each block is "linked" to the next block using cryptographic signatures, shared and collaborated among anyone with sufficient authority [10], and collaboratively maintains the authenticity of ledgers through consensus algorithms.

## IV. System Analysis

### A. User Analysis

The evaluation system is mainly for relevant users of the operational skill competition. The main users are teachers and students. The teacher is the leader of the competition mode and is responsible for the overall management of the competition. In addition, the teacher needs to configure the service of the blockchain and understand the specific situation of the competition, including viewing all experiment data stored by the blockchain system and their respective ratings. As participants in the competition, students will automatically upload indicator data to the blockchain system during the operation process, and the evaluation model will give scores according to the uploaded data. Teachers use the skill competition to test students' knowledge and ability to use knowledge.

### B. Functional Requirements

The relevant use cases are as follows:

- Blockchain service configuration. Teacher configures the appropriate blockchain service for each experiment, including whether to enable blockchain and configuration of data items.
- View the data item configuration. After the setting is completed, the teacher and students are able to view the configuration options.
- Upload the indicator data to blockchain. During the operation, students will automatically acquire and upload data to the blockchain system based on the evaluation model.
- View the uploaded data. For the data that has been uploaded to the blockchain, the teacher and students are supported to view all the data for each round.
- View the evaluation score. The teacher can view the score of each round of data given by the operational skill evaluation model.

### C. Key Technology

- Blockchain application framework. The system uses blockchain to assign users' respective nodes and accounts in the alliance chain, supports users to apply for certificates, and can customize the types of certificates for different needs. The user performs identity verification when applying for a certificate transaction.
- Operational skill evaluation model. This paper designs an evaluation model for the operational skill competition in the field of digital education. Taking e-commerce field

as an example, the evaluation model defines the first-level indicator as the enterprise performance. In order to evaluate the performance not only from the financial aspect, the balanced scorecard is used for multi-dimension evaluation, which defines finance, customer, internal process, learning and growth as four secondary indicators, and designs a multi-level operational skill evaluation model based on the specific roles and tasks of the operation system.
- Indicator weighting technique. In this paper, the fuzzy analytic hierarchy process is used to determine the weights of the operational skill indicator system. Fuzzy AHP is a combination of fuzzy comprehensive evaluation method and AHP, which improves the problems in the AHP.

### D. System Design Requirements

The operational skill competition evaluation system needs to meet not only the above functional requirements, but also the following requirements:

- Accuracy. The evaluation model of the system needs to have certain accuracy, so it is necessary to meet the strong correlation with the score data of the experts.
- Robustness. The system needs to handle errors correctly during execution, including errors from inside and outside of the system.
- Reliability. The system needs to run certain functions in a specific environment at a given time without errors.
- Ease of use. The design of the system needs to consider the user experience, meet the requirements of simple and easy operation, and ensure the clear display of related content.

## V. Operational Skill Evaluation Model

### A. Operation System Analysis

This paper takes the e-commerce operation sandbox as an example to design the operational skill evaluation model. The sandbox lets students simulate and operate an e-commerce platform. In the decision-making game of the turn-based system, the students' vocational skills and knowledge are cultivated and investigated. In the system, six operational roles are set up. During the operation, multiple students are responsible for different roles and cooperate with each other to complete the corresponding operational tasks.The operational roles are divided into the following six departments: Commodity Purchasing Department; Network Marketing Department; Financial Management Department; Customer Service Department; Logistics Distribution Department; Website Operation and Maintenance Department.

### B. Evaluation Indicator System

The sandbox simulates the operation of an e-commerce enterprise, so it is suitable to adopt the balanced scorecard evaluation system for enterprise performance evaluation. The first-level indicator is defined as the performance of enterprise, that is, the target layer. According to the balanced scorecard, the secondary indicators are defined as four dimensions:

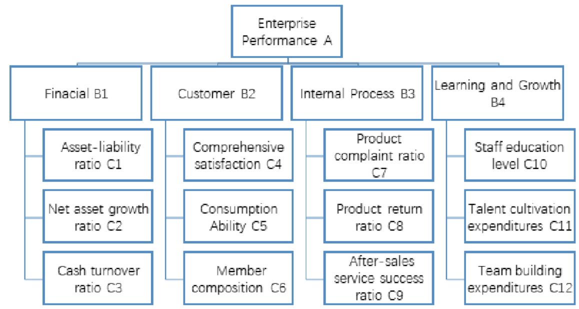


Fig. 1. Evaluation Indicator System

finance, customer, internal process, learning and growth, which constitute the criterion layer. And for each secondary indicator, refer to the evaluation indicators for e-commerce in the papers of Hong Wu [11], Ying Zhou [12], Ximin Jiang [13], Xun Hao [14], for the specific operational roles and operational tasks of the e-commerce operation sandbox, to design the following evaluation indicators:

Financial performance is the ultimate goal of enterprise, which indicates whether the current strategy adopted is beneficial to the profitability of the company. Financial indicator has the following indicators: Asset-liability ratio; Net asset growth ratio; Cash turnover ratio.

Since the main body is an e-commerce enterprise, the customer group is mainly members. Mastering the customer is the grasp of the market, and the customer's situation affects the sustainable development of the company. The customer indicator has the following indicators: Comprehensive satisfaction. The average value of customer price satisfaction, brand satisfaction, and service satisfaction; Consumption Ability; Member composition. Reflect the number and proportion of junior, intermediate and senior members.

The internal processes mainly focus on the product perspective, including the quality of the product itself and the handling after the problem occurs. The internal process indicator has the following indicators: Product complaint ratio; Product return ratio; After-sales service success ratio.

The training of employees and teams determines the future development of the company and is the cornerstone for the company's sustainable and healthy growth. Learning and growth indicator have the following indicators: Staff education level; Talent cultivation expenditures; Team building expenditures.

Based on the balanced scorecard model, this paper comprehensively evaluates the performance level of the company from four dimensions of finance, customer, internal process, learning and growth, which is the evaluation of students' operational skills. The operational skill evaluation indicator system constructed to cover the above four dimensions is shown in Figure 1:

TABLE I
IMPORTANCE SCALE TABLE

| **Preferences Expressed in Numeric Variables** | **Preferences Expressed in Linguistic Variables** |
|---|---|
| 0.5 | Equal impertinence |
| 0.6 | Moderate importance |
| 0.7 | Strong importance |
| 0.8 | Very strong importance |
| 0.9 | Extreme importance |
| 0.1,0.2,0.3,0.4 | Counter comparison |

### *C. Determination of Indicator Weight*

Based on the balanced scorecard model, this paper designs an operational skill evaluation indicator for the e-commerce operation sandbox. The evaluation indicator is multi-level and multi-dimensional. It is suitable to use the fuzzy analytic hierarchy process to determine the indicator weight. The steps are as follows:

*1) Establish a fuzzy complementary matrix:* In the fuzzy analytic hierarchy process, the indicators are compared in pairs, and the degree of importance is used to quantitatively represent the fuzzy judgment matrix. The quantity scale is usually given by the 0.1 to 0.9 scale method in the Table I [15].

For example, for the first-level indicator "enterprise performance" of the evaluation model, there are four secondary indicators B1, B2, B3, and B4. By comparing the four indicators in pairs, you can get the fuzzy complementary matrix between these indicators:

$$\text{R=}\begin{bmatrix} B_{11} & B_{12} & B_{13} & B_{14} \\ B_{21} & B_{22} & B_{23} & B_{24} \\ B_{31} & B_{32} & B_{33} & B_{34} \\ B_{41} & B_{42} & B_{43} & B_{44} \end{bmatrix} \tag{1}$$

Similarly, the respective fuzzy complementary matrices are constructed for the corresponding three-level indicators of the four secondary indicators.

*2) Consistency test of fuzzy complementary matrices:* If the constructed fuzzy complementary matrix does not have consistency, the matrix can be adjusted according to its properties to make it consistent. The specific adjustment method [16] is as follows:

Selecting a row compared to other elements that is more accurate in judgment, subtracting the corresponding element of the k (k = 2, 3, ..., n) row from the row element, if the obtained n differences are constant, there is no need to adjust the k row element, otherwise adjust it in the following way.

By the property of R, $r_{ij} = 1 - r_{ji}$, then $r_{11} + r_{kk} = r_{1k} + r_{k1} = 1$, then

$$r_{11} - rk1 = r_{1k} - r_{kk} = c(cisconstant) \tag{2}$$

$$r_{kj} = r_{1j}–c(j = 2, 3, \ldots, n, k \neq j) \tag{3}$$

After adjusting each row in turn, the matrix can be adjusted to a fuzzy consistent matrix.

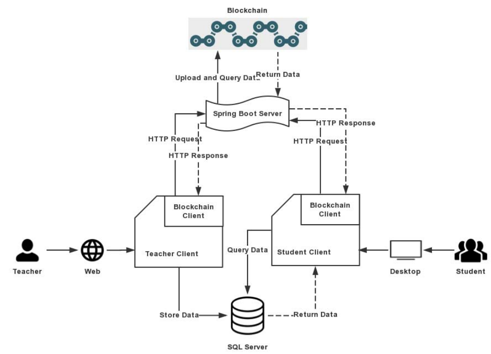


Fig. 2. System Architecture

*3) Hierarchical single ranking:* For the fuzzy consistency matrix, calculate the weight value of each element using the following weight calculation formula:

$$W_{\mathrm{i}} = \frac{\sum_{j=1}^{n} B_{ij} + \frac{n}{2} - 1}{n(n-1)} i = 1, 2, \cdots, n) \tag{4}$$

n is the order of R.

*4) Hierarchy general ranking:* On the basis of hierarchical single ranking, calculate the relative weight of each three-level indicator for the first-level indicator. For example, the weight of the three-level indicator asset-liability ratio relative to the first-level indicator is:

$$W_{C1} = W_{C1B1} W_{B1A} \tag{5}$$

$W_{C1B1}$ represents the weight of indicator C1 relative to B1, $W_{B1A}$ represents the weight of indicator B1 relative to A.

## VI. SYSTEM DESIGN

### *A. System Architecture*

The overall architecture of the system is shown in Figure 2. Teachers and students enter the teacher client and the student client through the web and desktop respectively. The teacher client and the student client complete the storage and retrieval of data through data communication with the database. On the other hand, the blockchain client is embedded in both the teacher client and the student client. The blockchain client communicates with the Spring Boot server through HTTP requests, and the server uploads the data to and queries the data from the blockchain system.

The system mainly includes three parts: operation module, evaluation module and blockchain module. The operation module is mainly composed of the student client and the teacher client, which is the system foundation. On the basis of it, support for blockchain services has been added, mainly including service configuration of blockchain, and uploading and obtaining data. The core content of the evaluation module is the evaluation model designed in this paper. Through the acquiring and processing of the indicator data, a comprehensive

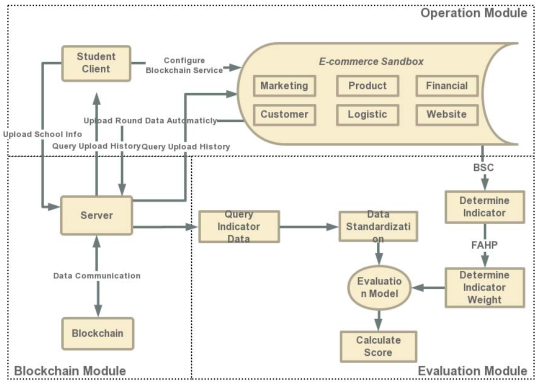


Fig. 3. System Principle

TABLE II
SERVER FUNCTIONS

| Function | Introduction |
|---|---|
| Remote service connection management | Configure and manage blockchain system remote service and rights management remote service. |
| Public and private key and certificate management | Local management of public and private keys, certificates, etc. |
| Certificate application | New user gets certificate to participate in blockchain system. |
| Certificate type application | A user holding a certificate initiates a certificate type transaction in the blockchain. |
| Build a deposit record | A user holding a certificate initiates a transaction for a certificate record in the blockchain. |
| Check whether the transaction is confirmed | Query the transaction status based on the transaction hash value. |

evaluation of operational skills is obtained. The blockchain module includes a blockchain system and a server for data communication, and the other two modules need to rely on the server for data communication.

### *B. Blockchain Application Design*

The application mode of the blockchain system mainly includes the following aspects:

- Mode selection: alliance chain. According to the blockchain technology, the application scenario in the operation competition system in this paper is defined as the alliance chain. The alliance chain is limited to the participations of alliance members, and the permissions of the blockchain are formulated according to the alliance rules.
- Participation policy. Suppliers of digital education operation products are required to join the blockchain. Schools that purchase digital education products can choose whether to join the blockchain. Third-party trusted federations can also join the blockchain, such as the Trusted Cloud in this paper. Each participant will have a node of their own.
- Operation and maintenance plan. The alliance chain network is jointly maintained by member institutions, and the digital education product suppliers provide the main operation and maintenance support, and the users operate and maintain their respective nodes.

The basic principles of blockchain module application mainly include decentralized trusted access through digital education blockchain, operating to enrich product evaluation, cross-school teaching and competition, and providing product reputation and traceability through digital education trusted cloud. The main functions of the server side responsible for data communication with the blockchain system are shown in the Table II:

### *C. Evaluation Module Design*

This section will describe the overall process of the evaluation model from the acquisition of original data to the evaluation of the school.

*1) Raw data acquisition:* According to the established evaluation indicator system, the original data corresponding to each indicator in the prototype system is selected for uploading. The data of some indicators can be directly obtained, and some indicators such as membership composition are obtained through calculation.

*2) Data standardization:* The data standardization method in this paper mainly uses the Softmax function.

The Softmax function, also known as the normalized exponential function. It can "compress" a K-dimensional vector $Z$ containing any real number into another K-dimensional real vector $\sigma(Z)$. Each element has a range between (0, 1) and the sum of all elements is 1. The representation of this function is:

$$\sigma(\mathbf{z})_j = \frac{e^{z_j}}{\sum\limits_{k=1}^{K} e^{z_k}} for\ j = 1, \dots, K. \tag{6}$$

*3) Round results calculation:* According to the obtained evaluation indicator system and its weight, the standardized data is taken as input, and the final score of the round is taken as an output to obtain the score of the group in the current round. The calculation method is:

$$G_0 = \sum_{i=1}^{K} A_i W_i \tag{7}$$

$A_i$ represents the data corresponding to each indicator, $W_i$ represents the weight of each indicator, and K is the number of indicators.

*4) Team scores calculation:* Each group has multiple rounds in one experiment, and each round is a progressive relationship, so as the experiment progresses, the importance of the later rounds increases gradually. When calculating the comprehensive team scores, different rounds are given different weights, and the final group score is calculated as:

$$G_1 = \sum_{i=1}^{M} G_i w_i \tag{8}$$

$G_i$ represents the scores of each round, $w_i$ represents the weight of each round, and M is the number of rounds.

*5) School scores calculation:* In order to obtain the rankings of all participating schools to achieve on-line competitions and games, it is necessary to comprehensively assess the school's scores based on the group's scores. Since the amount of data uploaded by each school is different, the best K teams are used. The results are used to assess the school's performance, calculated as:

$$G_2 = \frac{\sum_{i=1}^{K} G_i}{K} \tag{9}$$

$G_i$ represents the scores of each group and K is the number of teams.

## VII. Experiment

This article will test the evaluation model and system separately. For the evaluation model, this paper verifies the accuracy of the evaluation model by comparing the scores given by the evaluation model with the scores given by the experts in the competition. For the developed system, this paper designs the user scenarios of teachers and students separately, and verifies the technical feasibility of the prototype system by testing whether various functions are available.

### A. Evaluation Model Experiment

*1) Experimental Method:* The weights of the indicators and the synthetic weights of the evaluation indicator system calculated by the judgment matrix given by multiple experts are showing in Table III:

The experimental data is based on the indicators generated by the participating teams in the "E-Commerce Operational Skill" competition of the 2017 National Intelligent Manufacturing Vocational Skill Competition. It has a total of 12 teams, each group of 6 rounds, totaling 72 data.

The correlation coefficient is calculated by the scores given by the evaluation model and the scores given by the expert to verify the accuracy of the evaluation model.

*2) Experimental Results and Analysis:* Under the experimental data, the results calculated by the operational skill evaluation model proposed in this paper and the expert scores in the competition are shown in Figure 4. The expert scores are based on the percentage system, and the model scores are adjusted according to the calculated scores.

The correlation coefficient between two groups of data is 0.8347, which indicates that there is strong correlation, which proves that the accuracy of the operational skill evaluation model proposed in this paper performs well.

### B. System Experiment

*1) Test Case Design:* This article sets the experiment according to the system users' use scenarios, and tests the function indicators of the teacher and student roles in their own scenarios.

TABLE III
Evaluation Model Indicator Weight

| A Layer | B Layer | C Layer | Synthetic Weight |
|---|---|---|---|
| | | Asset-liability ratio C1 (0.317) | 0.105 |
| | Financial B1(0.332) | Net asset growth ratio C2 (0.417) | 0.138 |
| | | Cash turnover ratio C3 (0.266) | 0.088 |
| | | Overall satisfaction C4 (0.25) | 0.063 |
| | Customer B2(0.253) | Consumption ability C5 (0.425) | 0.017 |
| Enterprise Performance A1 | | Membership composition C6 (0.325) | 0.082 |
| | | Product complaint ratio C7 (0.309) | 0.074 |
| | Internal Process B3(0.24) | Product return ratio C8 (0.434) | 0.104 |
| | | After-sales service success ratio C9 (0.257) | 0.02 |
| | | Employee skill level C10 (0.417) | 0.073 |
| | Learning and Growth B4(0.175) | Talent cultivation expenditure C11 (0.317) | 0.055 |
| | | Team building expenditure C12 (0.266) | 0.047 |


Fig. 4. Scores Given by the Evaluation Model with the Experts

The teacher usage scenarios are mainly tested from three aspects: blockchain service default configuration; data selection; viewing history. The student usage scenarios are mainly tested from four aspects: automatically uploading round data; viewing blockchain service data item configuration; viewing data upload history; viewing software version history.

*2) Test Results:* The teacher use scenario results are shown in Figure 5. The test results show that the teacher role has the main functions of default configuration, data selection, and viewing history. The student use scenario results are shown in Figure 6. The test results show that the student role has four main functions: automatic uploading, viewing configuration,

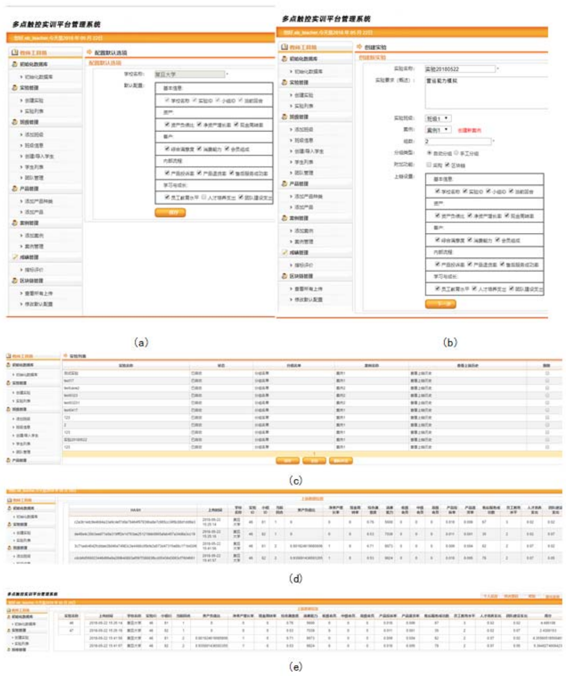

Fig. 5. Teacher Test Results

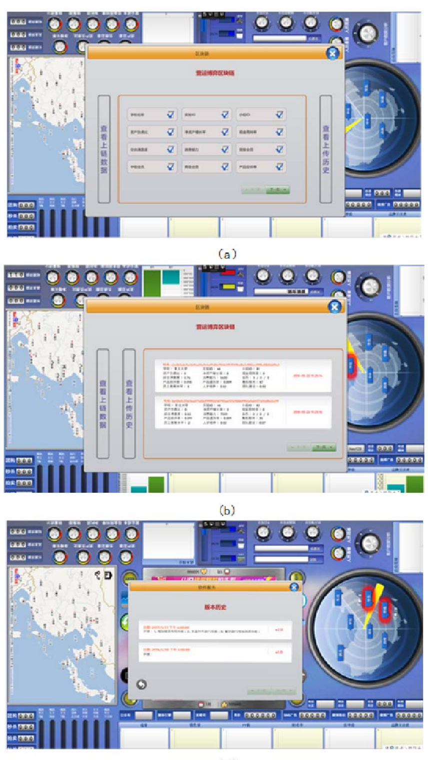

Fig. 6. Student Test Results

viewing data, and viewing version history.

In summary, the test basically completed several main functions such as data item configuration, data automatic uploading, deposit querying, covering the main usage scenarios of the two roles in the application. The test results are in line with the expected results, indicating that the evaluation system proposed in this paper is technically feasible.

### C. Design Requirements Test

According to the system design requirements, the accuracy is verified by the evaluation model experiment before. This section tests from three aspects: robustness, reliability, and ease of use.

- Robustness. The system makes a check at the user's data input, prompts for input that does not conform to the specification, or makes modifications to infer the correct input. The system handles errors in the communication with the database and blockchain services to ensure that there are no system crashes due to network connection errors, blockchain system errors, etc. It meets the requirement of robustness.
- Reliability. For the process of creating experiments by teachers, performing round operations, viewing operation data and scoring results, 10 sets of complete experiments were conducted, and no program collapse occurred. It meets the requirement of reliability.
- Ease of use. The teacher side is a web page that adopts a side menu bar form, which is easy for the user to select different functional modules. The student side is a desktop application. Blockchain and other services are in the form of a pop-up window, which is convenient for different students. So the system meets the requirement of ease of use.

## VIII. Summary and Forecast

This paper analyzes some shortcomings of the current competition mode and the application of blockchain in the field of digital education. In the current skill competition mode, the problems of unscientific competition and unauthorized evaluation make students and teachers less enthusiasm. And in on-line competition, the information is opaque and untrustworthy. The current application mode of blockchain is limited to the record of students' educational experience. The purpose is mostly to facilitate the employer's investigation of students, and also lacks evaluation and feedback on the storage data. To this end, this paper studies the blockchain-based operational skill competition evaluation system, and designs the blockchain application mode, participation policy, operation and maintenance plan and so on.

In the aspect of competition based on blockchain, this paper proposes a competition mode of applying blockchain technology based on the digital education operation sandbox. This mode applies blockchain technology to effectively simplify the competition process and improve competition efficiency. At the same time, the credibility of the competition is solved by the characteristics of system transparency and data non-tampering.

In the aspect of operational skill evaluation model, this paper takes the e-commerce operation sandbox as an example. According to the balanced scorecard, it proposes an evaluation indicator system for operational skills, and determines the weight of each indicator based on the FAHP. A comprehensive evaluation of operational skills is obtained according to the round, group, and school calculations.

This paper separately tests the evaluation model and system. In terms of evaluation model, this paper uses the expert scoring data in the competition, compared with the data calculated by the operational skill evaluation model proposed in this paper. The correlation coefficient obtained is greater than 0.8, which validates the accuracy of the evaluation model. On the system side, by simulating the teacher and student scenarios, the user's operations and data communication with the blockchain system are tested, which validates the technical feasibility of the prototype system.

Research will be conducted in the following aspects. Through the application of smart contract technology, the operational system can be effectively combined with the operational skill evaluation model proposed in this paper, and the contracts developed by the participants in the alliance chain can be automatically executed. The currently used FAHP relies too much on the subjective evaluation of experts. I consider using machine learning to train the evaluation model, and continuously optimize the model in the process of increasing the amount of data.

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