Research Article

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Research on the virtual simulation experiment evaluation model of e-commerce logistics smart warehousing based on multidimensional weighting

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Abstract: Through the analysis of the current research situation at home and abroad, this article finds that there is a lack of evaluation standards and methods in the virtual simulation experiment of e-commerce logistics smart warehousing. Therefore, it seriously affects the standardization and rationality of the experiment. To solve the problems in the evaluation of the current virtual simulation experiment, this article proposes a virtual simulation experiment evaluation model of e-commerce logistics smart warehousing based on multidimensional weighting. This article firstly sorts out the basic process of e-commerce logistics smart warehousing experiment activities and establishes the evaluation object. Then, based on the duality degree of the output results of the experimental steps, it proposes a method that conforms to the corresponding operation steps. Thus, a three-dimensional evaluation model of the completion degree of the operation steps, the reasonable degree of the operation steps, and the completion time of the operation steps are constructed. An automatic scoring evaluation model is proposed based on the combination of three-dimensional weighted evaluation of experimental steps. Finally, the feasibility and convenience of the evaluation model are verified through the experiment analysis.

Keywords: smart warehousing, virtual simulation, evaluation model, multi-dimensional, e-commerce logistics

1 Introduction

Currently, the virtual simulation experiment of e-commerce logistics smart warehousing relies on the actual scenarios of large e-commerce logistics centers such as JD.com, Cainiao, and Tmall. This simulation experiment simulates the actual operation of e-commerce logistics management and establishes a complete operation process of e-commerce logistics center. The characteristics of new retail e-commerce orders are as follows: multiple varieties, small batches, multiple batches, and short cycles. The irregular order distribution of e-commerce is simulated, and the dynamic storage strategy is combined to realize the effective implementation of the rapid operation of the e-commerce logistics center. The advanced "goods-to-person" operation mode is simulated in the system. The system can apply intelligent handling robots and automatic unmanned forklifts to realize the automatic handling of shelves and pallets. Therefore, it effectively solves the problems of high cost, high consumption, and irreversible operation of large-scale comprehensive training in the process of e-commerce logistics and warehousing.

This article first analyzes the research status of domestic virtual simulation experiments. Na [1] established a virtual simulation experiment examination system to evaluate the learning effect by examination results. Xuyang and Li [2] constructed the influencing factors of

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distance learning behavior in the virtual environment based on the unified theory of acceptance and use of technology model, which provided a research basis for subsequent learning effect evaluation. The author proposes an evaluation system of virtual simulation experiment teaching project in colleges and universities based on the fuzzy hierarchy method. This article establishes a comprehensive evaluation model based on the evaluation indicator system. The model uses the fuzzy analytic hierarchy process and Matlab program algorithm to obtain the weight of each indicator [3]. In this article, the first-level indicator items and the second-level indicator items of the virtual simulation experiment learning evaluation indicator system are determined, and the virtual simulation experiment learning evaluation indicator system is preliminarily constructed. In addition, this article uses analytic hierarchy process and questionnaire to determine the weight coefficient of each index item and sort it out. Finally, the learning evaluation indicator weights in the virtual simulation experiment environment are constructed [4].

On the basis of the support vector machine algorithm, this article proposes a multidimensional comprehensive evaluation method for software engineering from the aspects of time arrangement, task distribution, experimental tools, guidance methods, and teaching implementation [5]. Liu [6] combined with the back propagation neural network to construct a virtual experiment operation behavior evaluation model. Based on the network learning platform, the model collects students' online experimental operation behavior data and completes the feedback of the evaluation results of distance learners. The author proposes an evaluation model of ideological and political education based on the artificial neural network and the traditional multilayer fuzzy neural network. This model evaluates the ideological and political literacy of college students through virtual simulation experiments, which reflects the high application value of the fuzzy neural network model [7]. The article [8] uses the maximum information coefficient and deep learning methods to establish a learning behavior-learning ability "bimodal" online virtual simulation learning evaluation model. The model can improve the teaching effect of virtual simulation experiment courses. At the same time, the model can also promote the development of learning evaluation methods for multidisciplinary virtual simulation experiment courses.

An experiment assessment is a difficult point in experimental project design and experimental teaching organization. Through analysis and comparison, the existing problems in virtual simulation teaching are as follows: the development of experimental activities is still relatively random; the evaluation standards and methods of simulation experiments are relatively lacking. These deficiencies seriously affect the standardization, rationality, and validity of experiments. Then, research on the evaluation of scientific experimental activities has been carried out in the field of education, and fruitful results have been obtained. To ensure the objectivity, convenience, and comprehensiveness of the evaluation of experimental activities, the observational evaluation and the worksheet evaluation are combined to evaluate the physical experiment operation [9]. Through the design of the experimental process evaluation table, the quantitative evaluation of the experiment is carried out to standardize the physical and chemical experimental operation [10]. This article evaluates the virtual simulation experiment activities to achieve the purpose of judging the quality of experimental teaching, discovering problems and defects, and providing suggestions for improvement [11].

To solve the existing problems in the evaluation of the existing virtual simulation experiments, this article deeply studies the key factors in the evaluation of scientific experimental activities [12] and sorts out the basic process of e-commerce logistics experimental activities. This article combines the weighted evaluation of the following three factors: the completion degree of the experimental steps operation, the rationality of the experimental steps operation, and the completion time of the experimental steps. A virtual simulation experiment evaluation model of e-commerce logistics smart warehousing based on multidimensional weighting is proposed. The model is able to objectively measure the quality of conducting experimental activities. The purpose of this model is to facilitate the standardized and efficient implementation of experiments, so that recommendations can be made for the education sector based on the results of the evaluation.

2 The basic process of virtual simulation experiment of e-commerce logistics smart warehousing

An experiment is a series of experimental operations performed in a certain order. This article first sorts out the basic process of establishing the experiment and lays the foundation for the evaluation of the experimental activities. To enable students to deeply understand the business logic and theoretical knowledge of e-commerce logistics smart warehousing, we have designed a virtual simulation experimental teaching project for e-commerce logistics smart warehousing. The purpose of this experimental teaching is to improve the planning and design ability, operation data analysis ability, and operation management optimization ability of e-commerce logistics warehouse center.

The experimental teaching contains 30 knowledge points. According to the business logic and content of e-commerce logistics smart warehousing, the experiment is divided into three levels and ten steps. An experimental step is a single action node with a certain order and purpose in the experimental process, and the step consists of one or more experimental items. Triggered by the input conditions of the step, the step execution body implements it according to the relevant constraints and requirements and obtains one or more output items. Therefore, the three levels in this experiment are single operation experiment, design operation experiment, and comprehensive operation experiment. Then the ten experimental steps are as follows: e-commerce smart warehousing layout, e-commerce warehousing business operations, e-commerce goods-to-person picking business operations, e-commerce outbound business operation, e-commerce comprehensive warehousing business operation, e-commerce three-dimensional warehouse business design, e-commerce sorting business design, e-commerce circulation and processing business design, e-commerce outbound business design, and e-commerce comprehensive warehousing business simulation. Therefore, these ten steps can better describe the process of conducting experimental activities [13]. The overall flow of the experiment is shown in Figure 1.

3 Experiment evaluation model based on multiple dimensions

3.1 Examination requirements for virtual simulation experiments

When the experimenter completes the experiment, the experimenter will have a certain understanding of the business logic and theoretical knowledge of e-commerce

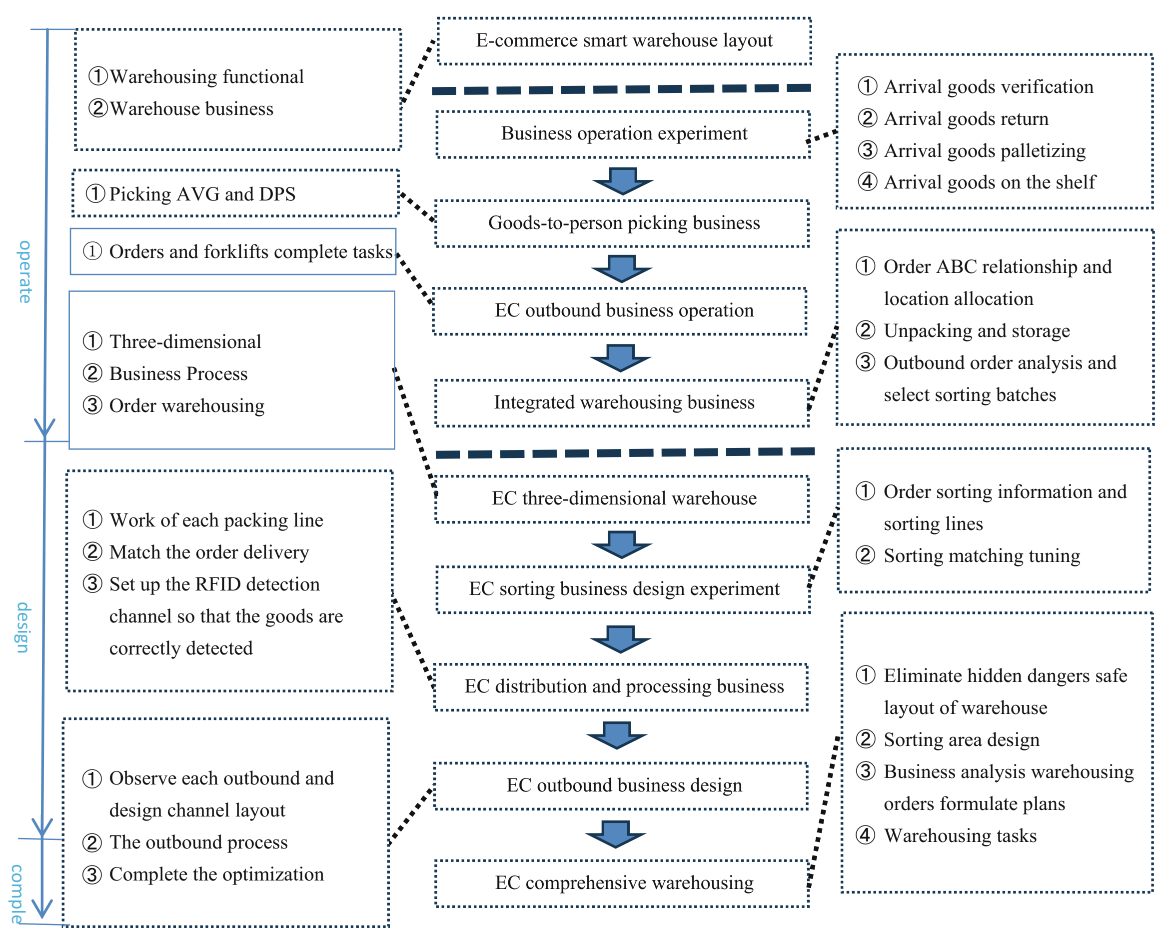

Figure 1: The basic process of virtual simulation experiment.

logistics smart warehousing [14]. The planning and design capabilities of e-commerce logistics and warehousing centers have been significantly improved. The practical ability of warehouse center operation in the e-commerce logistics link has been significantly improved. According to the different levels of ability improvement of the experimenter, this article proposes the following three levels of ability requirements.

Level 1 ability requirements (60–80 points). The experimenter can initially understand the operation process of the e-commerce logistics smart warehousing business. At the same time, the experimenter can simply design the e-commerce warehouse and connect the processes.

Level 2 ability requirements (80–90 points). The experimenter can basically master the operation process of the e-commerce logistics smart warehousing business. The experimenters carry out a reasonable design of e-commerce warehousing, which can ensure the stable operation of the warehousing process, and less occurrence of goods sorting errors, dumping, slipping, and other phenomena.

Level 3 ability requirements (90–100 points). The experimenter can master the operation process of the e-commerce logistics smart warehousing business. The experimenter conducts a reasonable e-commerce warehousing design, which can ensure the stable operation of the warehousing process and ensure that it achieves a high e-commerce warehousing efficiency.

3.2 Examination model of virtual simulation experiment

In this article, an examination model is developed according to the examination requirements of the experimenter. The examination is carried out from three dimensions: the completion degree of the operation steps, the reasonableness of the operation steps, and the completion time of the operation steps [15]. The examination method adopts the objective evaluation method. The total score of the experiment is to use the examination model to calculate the parameters collected by the system.

The examination model is as follows:

$$S = \sum_{i=1}^{10} A_i \times T_i \times (k_1 \times O_i + k_2 \times R_i), \tag{1}$$

where S represents the total score of the experiment, $S \in [0, 100]$; i represents experimental steps, $i \in \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\}$; A represents the corresponding score of experimental steps, $A \in [0, 100]$; T represents the time coefficient of experiment completion, $T \in [0, 1]$; O represents completion score of experiment steps, $O \in [0, 1]$; R represents reasonableness score of experimental operation, $R \in [0, 1]$; and $\boldsymbol{k}_1$, $\boldsymbol{k}_2$ represent weight factor, $k_1 = 60\%$, $k_2 = 40\%$.

The value range of the parameter variables of the examination model is presented in Table 1.

3.2.1 Corresponding scores for experimental steps

The corresponding score for the experimental step is coefficient A. The coefficient is formulated according to the dimensions of experiment type, experiment requirement ability, experiment challenge degree, and so on (Table 2).

3.2.2 The completion time coefficient of the experimental step

The completion time of the experimental step is the coefficient T. The value range of this coefficient is 0–1. The gradient division of the time coefficient for the completion of the experimental steps is formulated based on factors such as suggested class hours and experimental difficulty. For the setting process of the coefficient, this article first refers to the suggested class hours of the experiment. The coefficient for completion within class hours is 1. For the part beyond the recommended class

Table 1: Value range of model variables

Variable names	Value range
S (total score)	[0,100]
i (experimental steps)	{1,2,3,4,5,6,7,8,9,10}
A (corresponding scores for experimental step)	[0,100]
T (time coefficient of experiment completion)	[0,1]
O (completion of experimental steps)	[0,1]
R (the rationality of experimental steps)	[0,1]

Table 2: Experimental steps scores

Experimental steps	1	2	3	4	5	6	7	8	9	10
Corresponding scores	5	5	5	5	5	15	13	13	14	20

hours, the coefficient is 120 s gradient. The average of each gradient is taken as the actual completion time [16]. Finally, the coefficient is decreased, and the decreasing coefficient is obtained by averaging the scores of the project team members based on the importance of the experimental steps and the difficulty of the experimental steps. Therefore, it is formed as shown in equation (2).

$$T_i = \begin{cases} 1, & t_i < t_0, \\ \min(t_0/t_i \times N_i, 1), & 3t_0 > t_i > t_0, \\ 0, & t_i > 3t_0, \end{cases} \quad (2)$$

where T_i represents the completion time coefficient of the ith experimental step, $T_i \in [0, 1]$; t_0 represents the suggested class hours for the ith experimental step, $t_0 \in (0, +\infty)$; t_i represents the actual completion time of the ith experimental step, $t_i \in (0, +\infty)$; and N_i represents the experimental difficulty of the ith experimental step, $N_i \in [0.8, 1.2]$.

Through equation (2), the completion time coefficient table of the final experimental steps can be calculated, as shown in Table 3.

3.2.3 Completion of experimental steps

The degree of the completion of the experimental steps is obtained by comprehensive scoring by experts through factors such as the importance, difficulty, and completion of each knowledge point. After completing the score requirements in the experimental steps, the corresponding score ratio can be obtained (Table 4).

3.2.4 The rationality of experimental steps

The rationality of the experimental steps is obtained by comprehensive scoring by experts through factors such as the importance and difficulty of each knowledge point. After completing the score requirements in the corresponding experimental steps, the corresponding score ratio can be obtained, as shown in Table 5.

4 Case analysis of virtual simulation experiment evaluation model

4.1 Analysis of Pearson's correlation coefficient

The Pearson correlation coefficient is also known as the Pearson product moment correlation coefficient. The Pearson correlation coefficient is a linear correlation coefficient and is the most commonly used correlation coefficient. Denoted as r, it is used to reflect the degree of linear correlation between two variables X and Y. The r value is between −1 and 1. A larger absolute value indicates a stronger correlation. The sample correlation coefficient can be obtained by estimating the covariance and standard deviation of the sample [17]. The specific formula is as follows:

Table 3: Completion time coefficient table of experimental steps

Experimental steps Completion time (s)	1	2	3	4	5	6	7	8	9	10
(0, 300)	1	1	1	1	1	1	1	1	1	1
[300, 420)	0.5	0.85	0.8	0.95	0.9	1	1	1	1	1
[420, 540)	0.3	0.75	0.6	0.8	0.8	1	1	1	1	1
[540, 660)	0.1	0.6	0.4	0.6	0.7	1	1	1	1	1
[660, 780)	0	0.5	0.2	0.4	0.6	0.9	0.95	0.9	0.9	0.95
[780, 900)	0	0.4	0	0.2	0.5	0.85	0.9	0.8	0.8	0.9
[900, 1,020)	0	0.3	0	0.1	0.4	0.8	0.85	0.7	0.7	0.85
[1,020, 1,140)	0	0.2	0	0	0.3	0.7	0.8	0.6	0.6	0.8
[1,140, 1,260)	0	0.1	0	0	0.2	0.6	0.7	0.5	0.5	0.75
[1,260, 1,380)	0	0	0	0	0.1	0.5	0.6	0.4	0.4	0.7
[1,380, 1,500)	0	0	0	0	0	0.4	0.5	0.3	0.3	0.65
[1,500, 1,620)	0	0	0	0	0	0.3	0.4	0.2	0.2	0.6
[1,620, 1,740)	0	0	0	0	0	0.2	0.3	0.1	0.1	0.5
[1,740, 1,860)	0	0	0	0	0	0.1	0.2	0	0	0.3
[1,860, 1,980)	0	0	0	0	0	0	0.1	0	0	0.1
[1,980, +∞)	0	0	0	0	0	0	0	0	0	0

Table 4: Completion score in each procedure

No.	Name of each steps	Score points	Score ratio
1	Layout of e-commerce logistics smart warehousing	Drag into the reservoir area to black CAD bottom plate	0.1
		Drag out of the reservoir area to black CAD bottom plate	0.1
		Drag automated storage area to black CAD bottom plate	0.2
		Drag working-storage section to black CAD bottom plate	0.1
		Drag transport sorting area to black CAD bottom plate	0.2
		Drag transport operation area to black CAD bottom plate	0.2
		Drag packing and sealing area to black CAD bottom plate	0.1
—	—	—	—
		—	—
5	E-commerce integrated warehousing Business operation	E-commerce order data analysis	0.2
		Six pallets of goods are sorted into class A, B, and C	0.1
		Shelving class A, B, and C goods(total 96 pieces)	0.1
		Order of class A goods out of the warehouse	0.2
		Order of class B goods out of the warehouse	0.2
		Order of class C goods out of the warehouse	0.2
6	E-commerce stereoscopic warehouse Business design	Adjust the studio setup	0.2
		Complete one piece of goods in warehouse	0.4
		Complete one piece of goods out of warehouse	0.4
—	—	—	—
		—	—
10	E-commerce integrated warehousing Business simulation	Drag all storage sections to warehouse	0.1
		Design at least one Storage device in bulk storage area	0.1
		Design at least one warehouse fire protection equipment	0.1
		Design at least one belt conveyer in distribution area	0.3
		A pallet of goods goes into storage	0.2
		Sorting and packing of an order	0.2

Table 5: Rationalization score in each procedure

No.	Name of each steps	Score points	Score ratio
1	Layout of e-commerce logistics smart warehousing	Drag into the reservoir area to the right position	0.1
		Drag out of the reservoir area to the right position	0.1
		Drag automated storage area to the right position	0.2
		Drag working-storage section to the right position	0.1
		Drag transport sorting area to the right position	0.2
		Drag transport operation area to the right position	0.2
		Drag packing and sealing area to the right position	0.1
—	—	—	—
		—	—
5	E-commerce integrated warehousing Business operation	Correctly analyze three types of goods in the order	0.6
		Correctly answer storage knowledge questions	0.4
6	E-commerce stereoscopic warehouse Business design	Adjust the parameters to reach the maximum power within the range	0.2
		Complete 36 pieces of goods in warehouse	0.4
		Complete 36 pieces of goods out of warehouse	0.4
—	—	—	—
		—	—
10	E-commerce integrated warehousing Business simulation	Drag all storage sections to warehouse	0.1
		Design at least six storage devices in bulk storage area	0.1
		Design at least 15 warehouse fire protection equipment in warehouse	0.1
		Complete the design of distribution area (at least 5 exits and 30 pieces of goods)	0.2
		Complete warehousing of 11 pallets of goods	0.2
		Sorting and packing of 11 orders	0.2
		Complete the delivery of 100 pieces of goods from each of the five exits of the warehouse	0.1

$$\rho(X \cdot Y) = \frac{\sum(X - \overline{X})(Y - \overline{Y})}{\sqrt{\sum(X - \overline{X})^2 \sum(Y - \overline{Y})^2}}. \quad (3)$$

In formula (3), X and Y are two variables, and $\overline{X}$ $\overline{Y}$ denote the mean values of X and Y respectively.

1. When the correlation coefficient is 0, the two vectors X and Y are not correlated.
2. When the value of X increases (decreases) and the value of Y decreases (increases), the two vectors of X and Y are negatively correlated, and the correlation coefficient is between −1.0 and 0.0.
3. When the value of X increases (decreases) and the value of Y increases (decreases), the two vectors of X and Y are positively correlated, and the correlation coefficient is between 0.0 and +1.0.

The Pearson correlation coefficient is an upgrade of the Euclidean distance. It provides different processing steps for variable value ranges. Differences in the dimensions of the different variables are removed during the calculation. The Pearson correlation coefficient is an improvement of cosine similarity in the case of missing dimension values.

4.2 Analysis of the experiment

To verify the feasibility of the proposed experimental procedure evaluation method and experimental activity comprehensive evaluation method, an actual case is analyzed in this article.

The virtual simulation experiment of e-commerce logistics designed in this article has entered the national experimental space [18]. At the same time, experiments are carried out in more than 10 colleges and universities. A total of 421 students from these colleges and universities participated in the experiment, of which 247 students completed the project experiment. The average test time was 283 min. A total of 179 students achieved excellent grades, 68 students achieved the standard, and no student failed to meet the standard. The test completion rate is 100%, and the test pass rate is 100%. The experimental content is rated 4.9, the operating system is rated 4.7, and the support service is rated 4.8. The experiment time is reasonable. Through the virtual simulation experiment, the results of the experiment can reflect the ability level of the students.

The following is an experiment in a class to verify the evaluation model of the virtual simulation experiment proposed in this article. There are 31 people in this class who have completed the experiment. The longest time is 277 min, and the shortest is 160 min. The average time is 197.06 min, and the standard deviation is 26.127. The results of the experiment are as follows: the highest score is 100 points and the lowest score is 77 points. The average score is 88.06, and the standard deviation is 7.057. The maximum number of logins was 28, the minimum was 2, the average was 8.77, and the standard deviation was 6.109. The results and time of this experiment are within the acceptable range (Table 6).

Through experimental analysis, the time taken by a student to complete 10 virtual simulation experimental steps is presented in Table 7. After a student completes 10 virtual simulation experiment steps, the results obtained are presented in Table 8.

Correlation analysis is carried out on the data in Table 9. This article uses the Pearson correlation coefficient method for correlation testing. The experiment mainly conducts correlation analysis on the count of logins, time, and grade of the experimenter. The experimental results are presented in Table 10.

The results of the analysis show that grades are negatively correlated with time. The results of this correlation show that the more time students spend working on the project, the lower the grades they get. Therefore, it can be concluded that students' understanding, mastery, and proficiency of knowledge are not enough, which have a negative impact on their grades. The score is weakly correlated with the number of logins, and the number of logins has little effect on the score. Completion time

Table 6: Experimenter's Data Description

Stu_no	Count	Time	Grade
202,244,001	15	220	86
202,244,007	4	181	98
202,244,011	17	188	93
202,244,014	5	160	98
202,244,128	2	220	82
202,244,019	7	167	98
202,244,022	7	166	87
202,244,034	4	259	75
202,244,037	3	204	83
202,244,046	19	203	92
202,244,052	17	203	93
202,244,055	8	175	93
202,244,058	14	209	88
202,244,061	8	184	93
202,244,070	7	222	82
202,244,073	4	180	98
202,244,076	5	200	93
202,244,082	4	207	88
202,244,085	11	179	87

Table 7: Time spent by students in each step (minutes)

Stu_no	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Time
202,244,011	8	10	7	7	23	16	39	5	20	53	188
202,244,052	6	10	5	9	26	14	37	6	25	65	203

Table 8: Student grades by step

Stu_no	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Grade
202,244,011	5	5	5	5	3	15	13	13	14	15	93
202,244,052	5	5	5	5	3	15	13	13	14	15	93

Table 9: Descriptive statistics of student experiment test results

	Average	Standard deviation	Number of cases
Count	8.77	6.109	31
Time	197.06	26.127	31
Grade	88.06	7.057	31

Table 10: Correlation analysis of three-dimensional assessment elements

Correlation				
		Count	Time	Grade
Count	Pearson's correlation	1	−0.035	0.109
	Significance		0.852	0.561
	Number of cases	31	31	31
Time	Pearson's correlation	−0.035	1	−0.346
	Significance	0.852		0.057
	Number of cases	31	31	31
Grade	Pearson's correlation	0.109	−0.346	1
	Significance	0.561	0.057	
	Number of cases	31	31	31

is negatively correlated with the number of logins. The more login times, the more times students practice, the higher the proficiency, and the shorter the completion time.

After the examination of e-commerce logistics virtual simulation experiment, this article makes a score distribution map according to the students' scores, as shown in Figure 2. The examination results show that the student's grades are skewed to the normal distribution, and the expected value is skewed to the right. It shows that the students are more familiar with the experimental content, and the students' knowledge, proficiency, and accuracy of the experiment have been

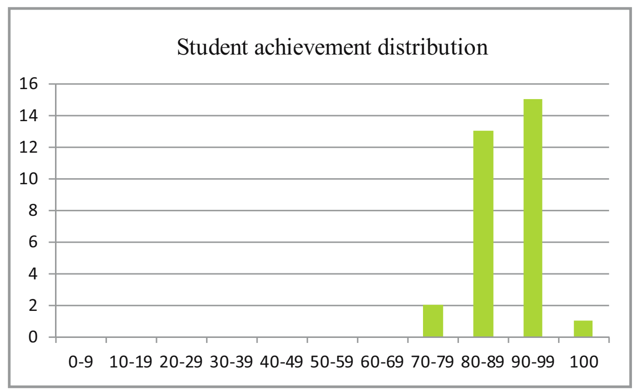

Figure 2: Student achievement distribution map.

significantly improved. Therefore, the results of the experiment become a normal distribution, which is in line with examination expectations.

5 Conclusion

As we all know, scientific, objective, and true evaluation of experimental activities is an important guarantee for steadily improving the experimental level. This article proposes an experimental activity evaluation method on the basis of sorting out the basic experimental process covering the whole life cycle of the experiment. This article proposes an evaluation method of experimental steps based on the combination of multidimensional and weighted evaluation, which can objectively and conveniently give the evaluation scores of the inspection items of experimental steps. This method is a useful exploration of the evaluation method theory. The research work can provide method support for the evaluation of experimental activities and is of great significance to promote the standardization and efficient development of experiments. The evaluation model of the virtual simulation experiment proposed in this article cannot reflect the requirements of advanced hierarchy, innovation, and challenge in experimental steps. The future research work is to divide the ten steps in the virtual simulation experiment into four modules according to the requirements of advanced hierarchy, innovation, and challenge. Each module designs a different evaluation model. If the effect of the model on grades is skewed to a normal distribution, the model parameters can be adjusted so that grades are normally distributed.

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