

## Retraction

# Retracted: Reforming the Teaching of Engineering Cost Budgeting Majors by Integrating VR and BIM Technology under the Internet of Things

### Security and Communication Networks

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### References

- [1] Y. Zhang and H. Mo, "Reforming the Teaching of Engineering Cost Budgeting Majors by Integrating VR and BIM Technology under the Internet of Things," *Security and Communication Networks*, vol. 2022, Article ID 4183059, 13 pages, 2022.

## Research Article

# Reforming the Teaching of Engineering Cost Budgeting Majors by Integrating VR and BIM Technology under the Internet of Things

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With the continuous development of digital technology and the Internet of Things (IoT), the teaching methods for architecture major in higher vocational colleges have also undergone major changes. New technologies and instruction methods in Engineering Cost Budgeting teaching can stimulate students' learning interest and improve education quality and students' comprehensive learning ability. In order to improve the teaching level of engineering cost budgeting major and stimulate students' interest in learning, this work first introduces backpropagation neural network (BPNN) into engineering cost estimation (ECE). Then, the BPNN-based ECE model is trained by the sample data to estimate the project's total quotation and comprehensive unit price. The error between the real and predicted values is analyzed. Second, the building information modeling (BIM) technology and virtual reality (VR) technologies are integrated into teaching engineering cost budgeting. The investigation, research, and analysis are conducted before and after applying BIM and VR technology in practical teaching. The results show that the proposed BPNN-based ECE model-estimated total quotation and comprehensive unit price fit well the sample values. The BPNN-based ECE model can be applied to teaching engineering cost budgeting. It can improve the calculation accuracy, and the relative error can be controlled within a certain range and has a certain potential to replace manual budgeting. It can provide some reference for the research of engineering cost technology. Classroom teaching under the integration of BIM and VR technologies can improve the students' homework quality, academic performance, and teaching quality to a certain extent. Integrating BIM and VR technology in classroom teaching can enhance students' communication, cooperation ability, oral defense scores, comprehensive scores, and professional skills.

## 1. Introduction

The widespread use of modern information technology has brought significant reform to engineering cost budgeting majors' teaching and learning methods. At the same time, with science and technological progress, such as the Internet of Things (IoT), under the background of vigorously promoting industrial upgrading and structural adjustment, the disadvantages of the traditional construction industry are prominent. China's construction industry will eventually break the traditional models and develop towards industrial, information, and intelligence development [1]. The demand of China's construction industry for comprehensive high-level talents with good practical ability, innovation ability,

teamwork ability, and social adaptability has become more urgent. This calls for the reform of the modern education mode. Adjusting the talent training mode of construction majors in higher vocational colleges (HVCs) to adapt to today's information-based and intelligent society has become urgent [2].

Engineering cost is a new discipline developed from the major of construction engineering management. The engineering cost budgeting major has a tedious theoretical knowledge. The teaching facilities are backward, the students' interest in theoretical teaching is not high, the overall practical experience is insufficient, and the professional skills are lacking [3]. Innovative professional technology research and innovative classroom teaching can better stimulate

students' interest, and there is more research in innovative teaching research. Lv et al. proposed immersive glasses to obtain primary geography learning by using human-computer interaction (HCI), 3D geographic information system (GIS), and virtual reality (VR) [4]. Shen and Ho designed a hybrid bibliometric method combining direct citation network analysis, text analysis, and cluster analysis. Then, they checked the relevant research articles retrieved from the science network database [5]. Chen et al. introduced the VR-based tracking technology. They verified the accuracy and training speed of the model algorithm by comparing the convolution neural network (CNN) model and the pre-training model of the classification data set [6]. Sun, from the perspective of positive psychology, explored the impact of the "Internet + Maker education" college innovation and entrepreneurship education (IEE) model on college students' innovation and entrepreneurship ability [7]. Yan and Lv simulated the face-to-face social interaction based on scene roaming, real-time voice capture, and action capture, compared the differences between social communication and traditional plane social communication, and analyzed the advantages and disadvantages [8]. Most of the above literature is unilateral research on technological innovation, and the research on combining technology and teaching is less, especially in the construction industry teaching. Building information modeling (BIM) technology has a high degree of visualization in the design environment. It supports the analysis and optimization of schemes by various building performance software at any design stage. Its visual characteristics enable students to quickly understand the project's building function, structural space, and design intention [9]. Virtual reality (VR) technology provides a good "roaming experience" for building users and architects, which can be applied in the process of scheme design evaluation, demonstration, and proof [10]. Integrating BIM and VR technologies to establish an efficient integration system can simulate all stages of the building and improve the application of sustainable design in the building [11]. New technology can improve the accuracy of engineering cost estimation (ECE), and technical reform is also an important part of architectural major in colleges and universities [12]. Compared with traditional ECE methods, backpropagation neural network (BPNN) technology can calculate the engineering cost more accurately and conveniently. Meanwhile, it has robust learning, nonlinear mapping, information processing, and antiinterference abilities. These vital functions provide the possibility of applying BPNN in ECE. It is a new ECE model [13].

First, this work introduces the BPNN model to build an ECE method, carries out test training, and analyzes the error between the real and test values. The purpose is to improve the engineering cost budgeting methods and calculation accuracy. Second, it researches engineering cost budgeting majors' teaching mode, integrates BIM and VR technologies, and analyzes the teaching situation. Here, the BPNN is used to implement the ECE model to improve the budgeting accuracy and has certain potential to replace manual budgeting by controlling the relative errors. Classroom teaching by integrating BIM and VR can improve the

students' homework quality, their academic performance, and teaching quality to a certain extent. It is hoped to provide a reference for teaching reform.

## 2. Research on Theoretical Basis and Method of Engineering Cost

### 2.1. Engineering Cost Theory

*2.1.1. Meaning of Engineering Cost.* Engineering cost budgeting covers various courses, such as computer, engineering technology, and cost technology. It is a highly comprehensive major. From the investor's perspective, engineering cost is the total cost of a series of activities in the whole process, from investment decision to project completion acceptance [14]. Engineering cost refers to the contract price of a construction project determined by the market from market transactions. In construction projects, the price recognized by the demand subject and supply subject is finally formed by the market based on multiple estimates through contract awarding and contract transactions [15]. The specific contents of engineering cost budgeting are shown in Figure 1.

As shown in Figure 1, the engineering cost includes the total construction investment and interest during the construction period. The total construction investment includes the project cost, other construction costs, and reserve funds. The project cost specifically includes construction and installation cost and equipment purchase costs. By comparison, reserve funds include basic reserve funds and price-increase reserve funds for price increases. Thus, the engineering cost covers all construction project costs, and ECE is very important for the whole engineering cost management.

*2.1.2. Characteristics of Engineering Cost.* Engineering cost features large scale, single personality, dynamism, hierarchy, and multiplicity [16]. Large scale refers to the huge form of construction projects, large resource consumption, high cost, and tens of millions or even hundreds of millions of funds invested. Single personality means that each construction project has its special purpose. Each project has a different structure, shape, plane layout, and equipment configuration requirements. Dynamism means that the construction project takes a long time from investment decision to completion and delivery. Engineering costs will be affected by many uncontrollable factors from the society, including engineering change, price change, rate, interest rate, and exchange rate may change. The construction project also has a hierarchy feature, namely an engineering complex divided into different levels: single projects, unit projects, divisional projects, and subdivisinal projects. Lastly, the engineering cost cannot determine the reliable price at one time and must be carried out many times at different stages of the construction procedure. This is called multiplicity, which ensures the scientificity of the determination and control of the engineering cost [17].

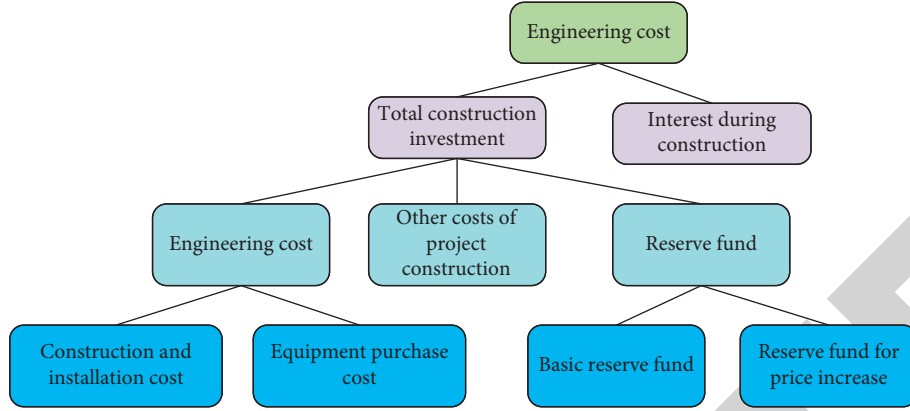


FIGURE 1: Composition of engineering cost.

2.2. *BPNN-Based ECE Model.* BPNN is divided into the input, hidden, and output layers. The BP learning algorithm mainly uses signal forward propagation and error back-propagation [18]. The two propagation processes are specified in Figure 2.

As shown in Figure 2(a), the training samples are transmitted from the input layer to the hidden layer when the signal propagates forward. Then, it is transferred to the output layer, layer by layer. An output result is obtained, and the error between the output and the expected values is calculated. If the error exceeds the set threshold, the error is back-propagated, as shown in Figure 2(b). The upward arrow indicates the direction of error backpropagation. Afterward, weight parameters are iteratively calculated. Suppose the error is less than the set threshold. In that case, the learning algorithm ends, and it is considered that the optimal model parameters have been obtained. The output error is back-propagated layer by layer through the hidden layer according to the forward path until the input layer. In the calculation process, the total error is allocated to each neuron in each layer. The error signals of each neural unit in the hidden layer are obtained as the basis for optimizing the weight. The gradient descent method (GDM) completes the back-propagation of the gradient. After continuously adjusting the neurons' weights in the gradient's descending direction, the total error signal is reduced to the minimum. Then, the model is considered to have obtained the optimal weight.

The process of continuously optimizing the weights and thresholds of the network model is the training process. The NN's weights and thresholds will be repeatedly adjusted and optimized through signal forward propagation calculation and error backpropagation [19].

The weight adjustment process is deduced by the BP algorithm. Assume that there are nodes  $= 0, 1, 2, \dots, m, k = 1, 2, \dots, l$  for the output layer; for hidden layers,  $i = 0, 1, 2, \dots, n; j = 0, 1, 2, \dots, m$ .

For the output layer, the weight adjustment  $\Delta\omega_{jk}$  is calculated by the following formula:

$$\Delta\omega_{jk} = -\eta \frac{\partial E}{\partial \omega_{jk}} = -\eta \frac{\partial E}{\partial \text{net}_k} \frac{\partial \text{net}_k}{\partial \omega_{jk}}. \quad (1)$$

In (1),  $\omega_{jk}$  is the weight of the output layer.  $E$  denotes the output error.  $\eta$  represents the learning rate [20].

For hidden layers, the weight adjustment  $\Delta v_{ij}$  is calculated by the following formula:

$$\Delta v_{ij} = -\eta \frac{\partial E}{\partial v_{ij}} = -\eta \frac{\partial E}{\partial \text{net}_j} \frac{\partial \text{net}_j}{\partial v_{ij}}. \quad (2)$$

In (2),  $v_{ij}$  is the weight of the hidden layer.

Error  $\delta_k^o$  and  $\delta_j^y$  are defined for the output layer and the hidden layer, respectively. They are, respectively, calculated by the following formulas:

$$\delta_k^o = \frac{\partial E}{\partial \text{net}_k}, \quad (3)$$

$$\delta_j^y = \frac{\partial E}{\partial \text{net}_j}. \quad (4)$$

Comprehensively considering (1), (2), (3), and (4) can determine the weight adjustment  $\Delta\omega_{jk}$  and  $\Delta v_{ij}$  of the output layer and hidden layer by the following formulas:

$$\Delta\omega_{jk} = \eta \delta_k^o y_j, \quad (5)$$

$$\Delta v_{ij} = \eta \delta_j^y x_i. \quad (6)$$

It can be seen that the error signal is calculated  $\delta_k^o$  and  $\delta_j^y$ , and then according to the descending direction of the gradient, the calculation of the weight adjustment amount can be completed.

For the output layer, the expansion process  $\delta_k^o$  reads

$$\delta_k^o = -\frac{\partial E}{\partial \text{net}_k} = -\frac{\partial E}{\partial o_k} \frac{\partial o_k}{\partial \text{net}_k} = -\frac{\partial E}{\partial o_k} f'(\text{net})_k. \quad (7)$$

For hidden layers, the expansion process of  $\delta_j^y$  reads

$$\delta_j^y = -\frac{\partial E}{\partial \text{net}_j} = -\frac{\partial E}{\partial y_j} \frac{\partial y_j}{\partial \text{net}_j} = -\frac{\partial E}{\partial y_j} f'(\text{net})_j. \quad (8)$$

The calculation of output error  $E$  reads

$$E = \frac{1}{2} (d - O)^2 = \frac{1}{2} \sum_{k=1}^l (d_k - o_k)^2. \quad (9)$$

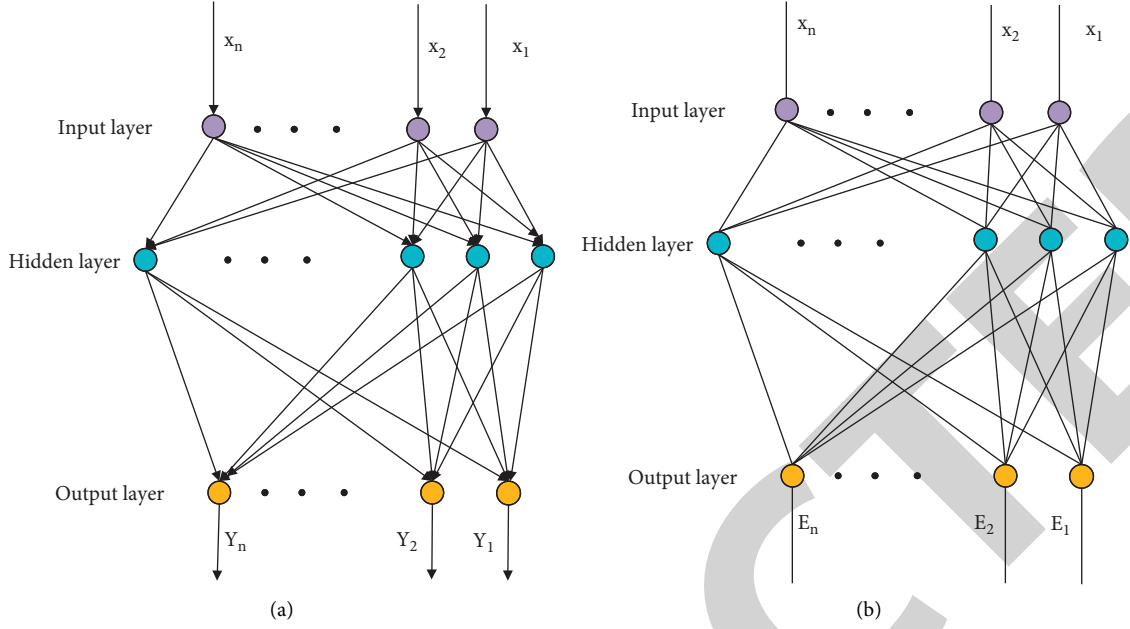


FIGURE 2: Propagation process (a) Signal forward propagation (b) Error back-propagation.

In (9),  $O$  is the output vector of the output layer, and  $d$  represents the desired output vector. Then,  $E$  can be calculated by expanding (9) to the hidden layer, as given in the following formula:

$$E = \frac{1}{2} \sum_{k=1}^l [d_k - f(\text{net}_k)]^2 \quad (10)$$

$$= \frac{1}{2} \sum_{k=1}^l \left[ d_k - f \left( \sum_{j=0}^m \omega_{jk} y_j \right) \right]^2.$$

According to (9) and (10),  $\partial E / \partial o_k$  and  $\partial E / \partial y_j$  can be calculated by the following formulas:

$$\frac{\partial E}{\partial o_k} = -(d_k - o_k), \quad (11)$$

$$\frac{\partial E}{\partial y_j} = - \sum_{k=1}^l (d_k - o_k) f'(\text{net}_k) \omega_{jk}. \quad (12)$$

Bringing (11) and (12) into (7) and (8) and applying  $\hat{f}'(x) = f(x)[1 - f(x)]$  can obtain the following formulas:

$$\delta_k^o = (d_k - o_k) o_k (1 - o_k), \quad (13)$$

$$\delta_j^y = \left[ \sum_{k=1}^l (d_k - o_k) f'(\text{net}_k) \omega_{jk} \right] f'(\text{net}_j)$$

$$= \left( \sum_{k=1}^l \delta_k^o \omega_{jk} \right) y_j (1 - y_j). \quad (14)$$

Bringing the above equations into (5) and (6) can obtain the weight adjustment calculation of the BP algorithm, as shown in the following formulas:

$$\Delta \omega_{jk} = \eta \delta_k^o y_j = \eta (d_k - o_k) o_k (1 - o_k) y_j, \quad (15)$$

$$\Delta v_{ij} = \eta \delta_j^y x_i = \eta \left( \sum_{k=1}^l \delta_k^o \omega_{jk} \right) y_j (1 - y_j) x_i. \quad (16)$$

**2.3. BIM Technology.** BI integrates all links in the whole construction project lifecycle to form the digital 3D model of the construction project [21]. A complete BIM model can show the building's 3D geometry, contain extensive information and data, and realize the whole process management from project planning to design, construction, operation, and maintenance [22]. BIM technological theory has experienced concept popularization, value application, digital application, and industrial application [23]. BIM is not a simple 3D model but includes building and application models. The established model covers two modules: product and specific process, and the application model is mainly the decision-making part [24]. BIM has the advantages of digitization, relevance and consistency, visual design environment, high compatibility, information sharing, and collaborative design [25]. Its collaborative design function is illustrated in Figure 3.

As shown in Figure 3, BIM technology provides a multidisciplinary collaborative design platform for the design, structure, construction, and other relevant departments of construction projects based on information integration. The platform's ultimate goal is to meet the project quality requirements, construction engineering requirements, urban planning requirements, quality and safety requirements, and architectural aesthetics. The platform provides information sharing and collaborative design for all architectural departments and disciplines. Each department includes architectural design, structural

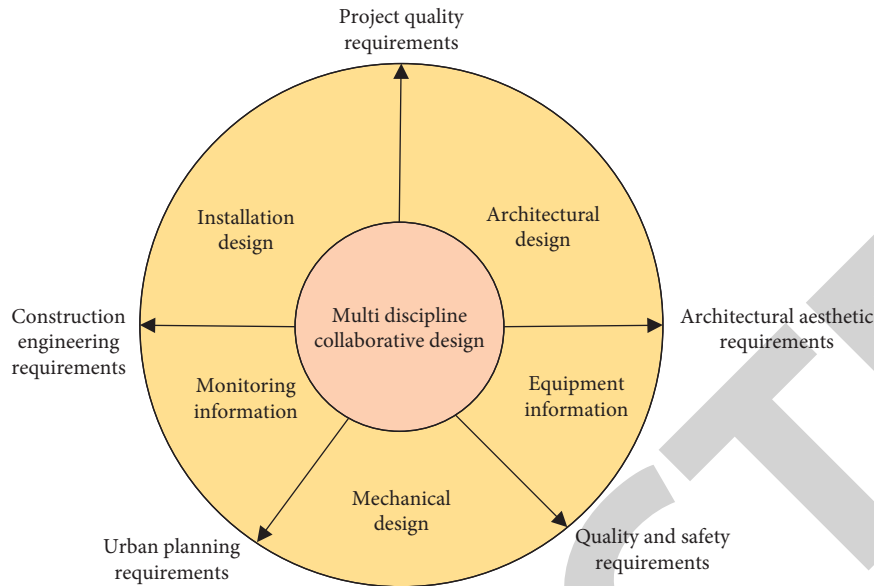


FIGURE 3: BIM collaborative design.

design, installation design, equipment data, and information monitoring. During the design implementation process, a large amount of information exchange between departments can be carried out. It makes up for the defects of the traditional architecture that all units and parts often act in their own way and lack the communication of scheme design.

Combined with the construction drawings of a project, some structural models in the project are created using BIM. The results are portrayed in Figure 4.

BIM helps to improve students' spatial imagination intelligence to stimulate students' interest in learning to explore further the relationship between building structures. Figure 4 draws the BIM 3D diagram of the cabin surface structure. BIM helps transfer students' two-dimensional (2D) cognition to 3D cognition, thus making the project budget calculation more accurate.

**2.4. Basic Theory of VR Technology.** VR is an interaction that simulates and experiences the virtual world, adds the 3D virtual model to the real scene in real space, and integrates real world and virtual information [26]. Using the interactivity of VR technology can well make up for the defects of lack of interaction and situational immersion in multimedia teaching of engineering cost course [27].

VR in architectural design has various features, as demonstrated in Figure 5.

The immersion is the most prominent feature of VR technology, mostly reflected in the degree of real feeling in the virtual scene. Interactivity mainly refers to the HCI of the VR system, which facilitates user control and monitoring. VR technology can also facilitate users to quickly understand the environment and stimulate deeper and more diversified user imagination. By integrating (networking) planning, design, and construction into a parallel design system, VR realizes interactive design.

Meanwhile, VR technology has high efficiency in modifying the virtual scene, communicating with users, and designing and optimizing schemes. Lastly, the VR system can realize multiperception, such as hearing, touch, taste, smell, and visual perception.

**2.5. Application of BIM and VR Mode in the Teaching of Engineering Cost Budgeting Major.** Construction project drawing and reading is the core course of engineering cost budgeting majors in HVCs. Cultivating students' ability to understand the design assignment or design change documents and skillfully read the construction drawings and supporting text documents is the key teaching goal for engineering cost budgeting major [28]. In BIM and VR mode, specific project tasks can be selected as learning methods to cultivate students' ability in map recognition, graphic calculation, and pricing. Applying BIM technology enables students to more comprehensively master the specific practical contents of engineering cost management (PCM) [29]. The classroom teaching process under BIM and VR technology is depicted in Figure 6.

The whole teaching design includes a theoretical part and a practical part. The teaching part can be divided into practical exercises and classroom teaching. The practice part is mainly project-task training, including BIM and VR skill training.

**2.6. Questionnaire Survey (QS) Design.** The engineering cost budgeting majors are investigated before and after using the BIM and VR technology in classroom teaching, and the user satisfaction is investigated. The QS is divided into two parts: one issued at the beginning of the study and another after one month to check the learning effect. The QS is mainly designed to understand the teachers' and students' opinions and satisfaction with the introduction of BIM and VR

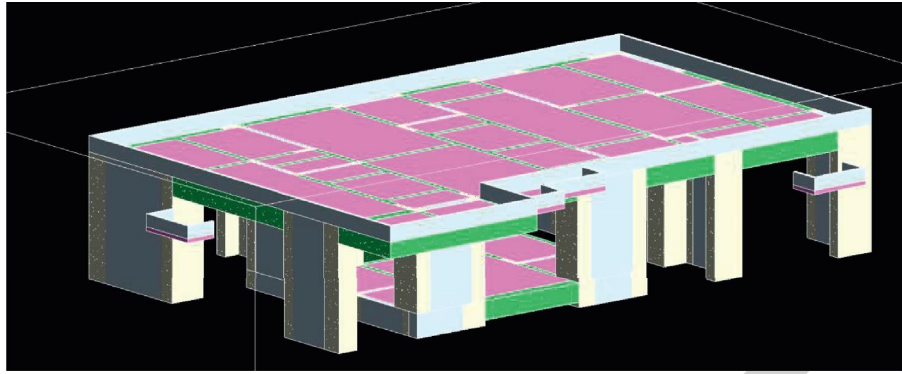


FIGURE 4: BIM 3D drawing of small cabin structure.

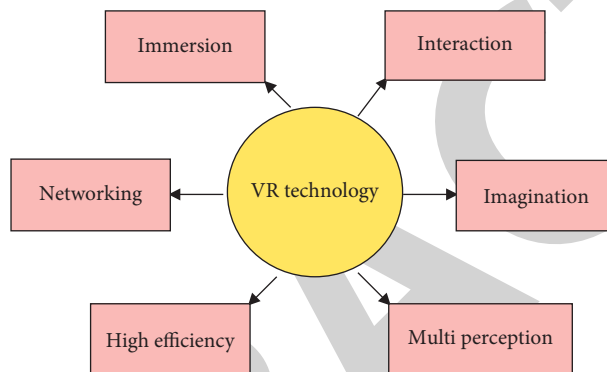


FIGURE 5: VR technical features.

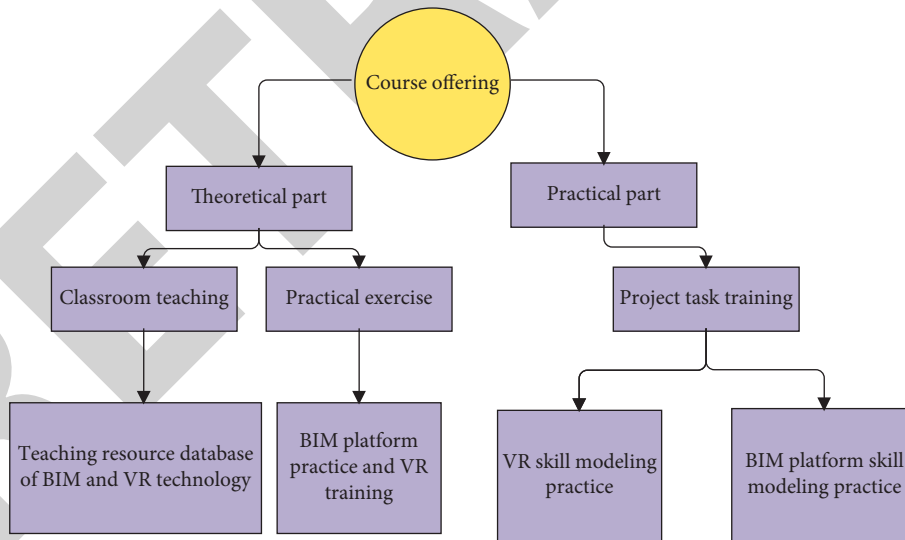


FIGURE 6: Course teaching process based on BIM and VR technology.

technology into the curriculum mode and the results achieved by the “project task-based” learning method in the core course of architectural engineering drawing reading. The research object is the students from engineering cost budgeting major in three architectural vocational schools in Guizhou Province. The classes of students in three different schools are set as engineering cost budgeting Class 1, Class 2, and Class 3. Altogether, 130 Qs are distributed, and 126

TABLE 1: Survey of the number of students.

Class	Gender	Population
Engineering cost budgeting class 1	Male	22
	Female	20
Engineering cost budgeting class 2	Male	22
	Female	19
Engineering cost budgeting class 3	Male	23
	Female	20

TABLE 2: NN model sample training dataset.

Sample	Building area height X1	Building area X2	Standard floor area X3	Standard layer height X4	Number of ground floors X5	Basement height X6	Number of basement floors X7	Basement floor area X8	Duration X9	Total cost Y	Comprehensive unit price V1	Comprehensive unit price V2	Comprehensive unit price V3
1	28.5	16745	1679	3	8	4.2	1	1669	1765	18004000	312	408	390
2	55.1	16667	846	2.9	18	0	0	0	1562	23919084	330	430	370
3	78	9566	342	3	26	4	2	674	674	13460431	460	402	407
4	20.3	4509	644	2.9	7	0	0	0	644	5326227	500	425	392
5	64.9	21800	991	2.95	22	0	0	0	991	41715826	390	384	412
6	46.2	9111	527	3	15	4.2	1	1205	728	17722079	410	401	380
7	60	8600	373	3	19	3	4	1500	380	23048000	510	397	401
8	70.6	19133	736	2.9	26	3	2	1466	736	31565432	530	403	397
9	75.9	22884	815	2.9	26	3	2	1675	815	42754602	310	410	395
10	98.9	40885	1515	3.6	25	3.7	2	4356	2138	43227463	518	380	405



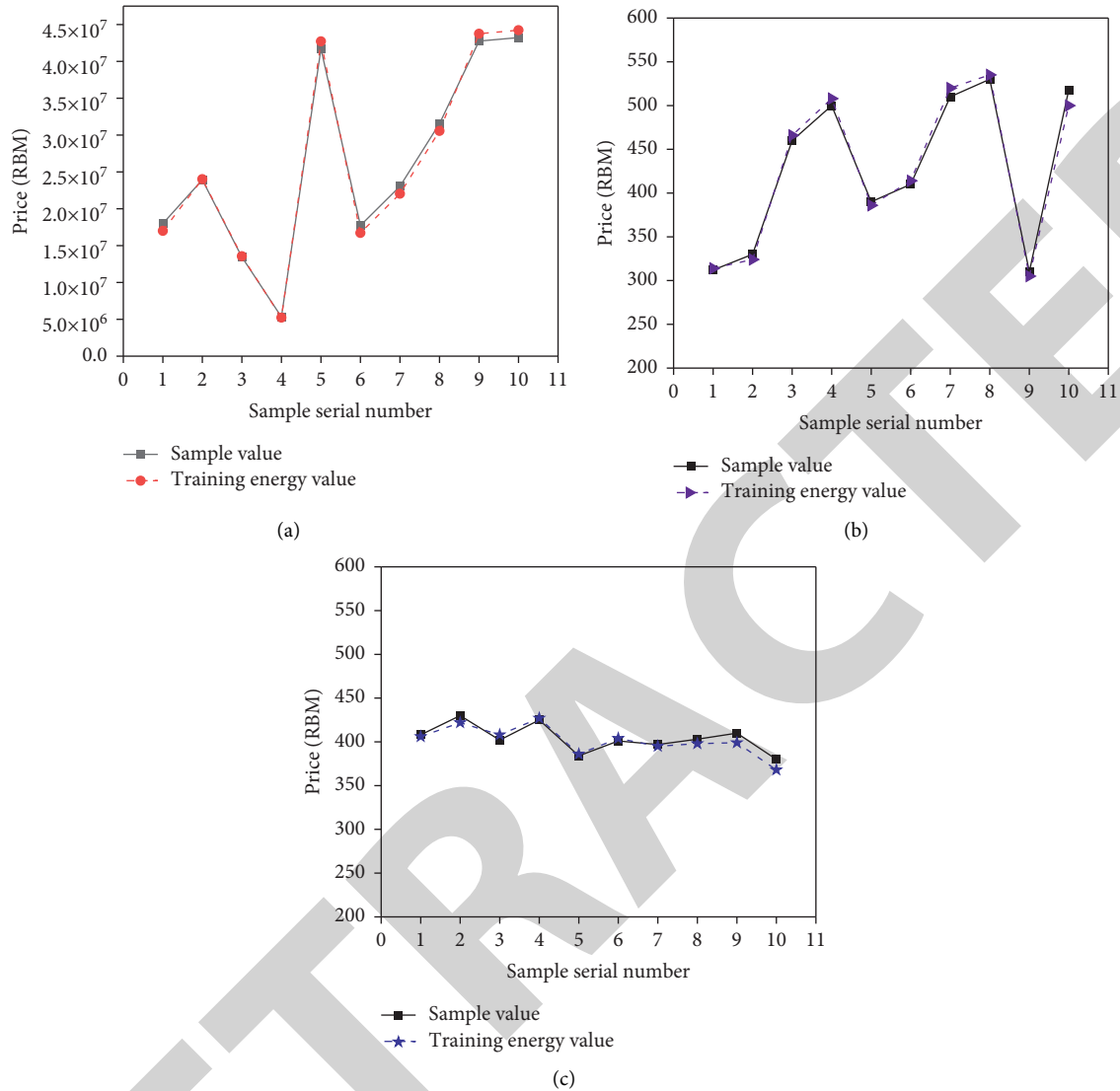


FIGURE 7: NN curve fitting. (a) Fitting results of total quotation; (b) Fitting results of comprehensive unit price V1; (c) Fitting results of comprehensive unit price V2.

valid ones are recovered, with a 100% valid recovery rate. Table 1 lists students' detail.

**2.7. BPNN-Based ECE Model Training.** The NN model program is written in Spyder software in a Python environment. The training algorithm of the model adopts the improved BP algorithm with momentum term. The purpose is to avoid the error curve falling into the local minimum as much as possible in the training process to obtain a better solution [30]. BP algorithm can quickly predict the engineering cost and improve the accuracy.

Through the cost information website, ten groups of engineering cost settlement data in a certain area in recent years are collected and sorted out as samples, nine groups as training samples, and one group as test samples. These data are used as the BPNN's training dataset, as shown in Table 2.

### 3. Results of Model Test

#### 3.1. Analysis of BPNN-Based ECE

**3.1.1. Fitting Curve Analysis of Total Quotation and the Comprehensive Unit Price.** The sample data train the BPNN-based ECE model, and the results are plotted in Figure 7.

From Figure 7, the fitting curve of the total quotation and comprehensive unit price is very close to the fitting curve of training value. The curve fitting effect is basically consistent. Thus, BPNN can play a positive role in ECE.

**3.1.2. Error Analysis of Comprehensive Unit Price.** Next, the error between the proposed BPNN-based ECE model's output and the real value is verified on the test set through random sampling. The results are explained in Figure 8.

As shown in Figure 8, there is a certain difference between the model output and the real value. For example,

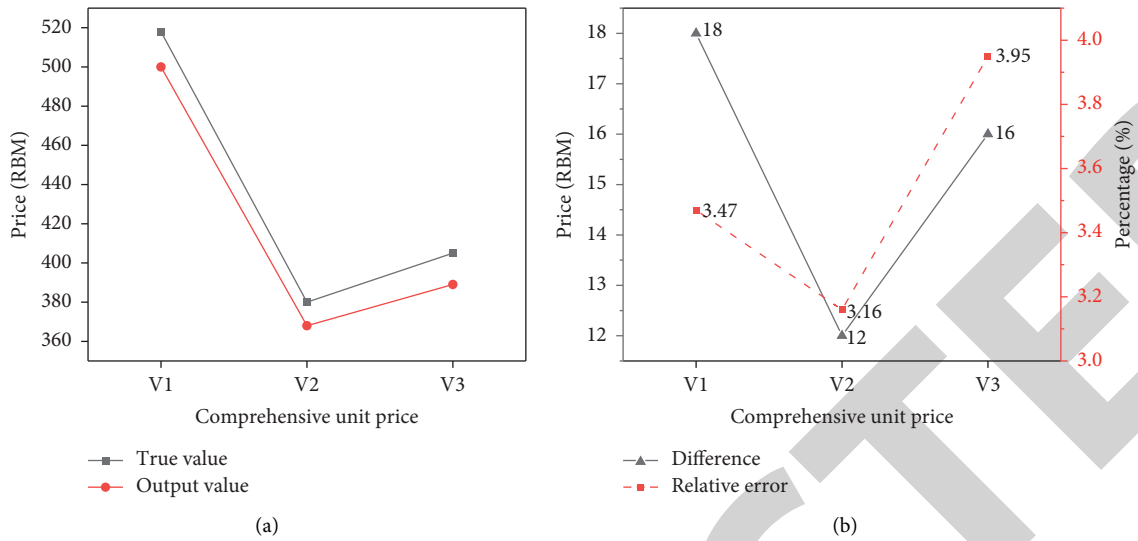


FIGURE 8: Error comparison (a) Comprehensive unit price; (b) Relative error.

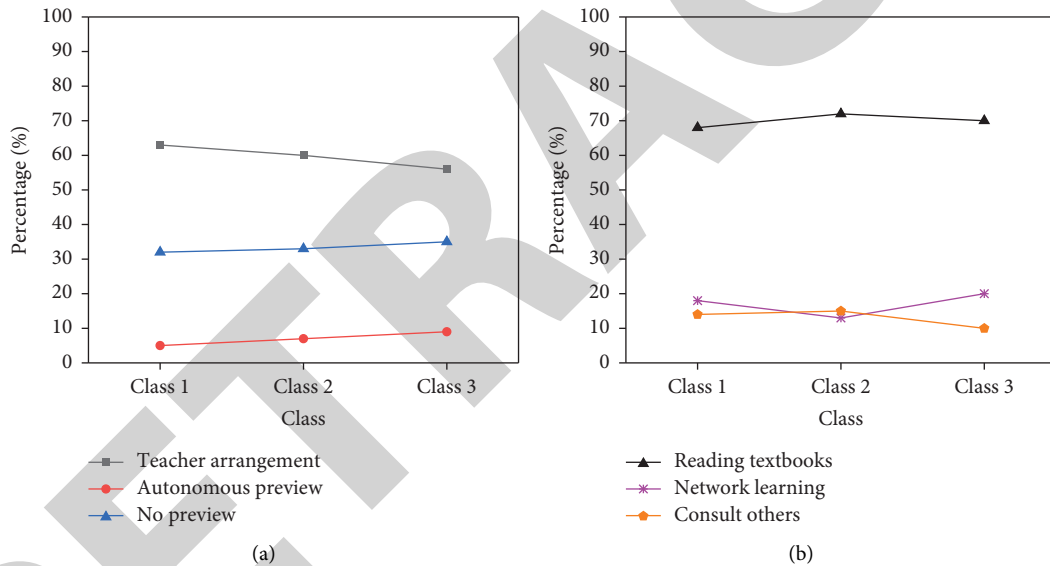


FIGURE 9: Preview QS (a) Comparison of preview enthusiasm; (b) Comparison of preview methods.

the difference in V1 is 18, in V2 is 12, and in V3 is 16. The relative errors of the three comprehensive unit prices are 3.47%, 3.16%, and 3.95%, respectively. Hence, the proposed BPNN can roughly estimate the cost of the construction project and can be used as a reference for the research of engineering cost budgeting majors' teaching methods.

### 3.2. Investigation and Analysis of the Teaching of Engineering Cost Budgeting Major before Using Technology

3.2.1. Analysis of Preview of Engineering Cost Budgeting Majors before Technology Application. The QS results of students' preview before the architectural project drawing and reading course are presented in Figure 9.

Comparing the three classes' previews shows that most students complete the assigned tasks according to teachers' requirements. More than 30% of the students do not preview, and less than 10% of students preview independently. The scope of the preview is relatively narrow. Students' preview situation of the three classes is roughly similar. On the premise of preview, more than 60% of students choose to read textbooks, and many students obtain online resources and other methods. Overall, most students' preview enthusiasm is not high, the method is monotonous, and they lack autonomous learning ability.

3.2.2. Analysis of Classroom Learning of Engineering Cost Budgeting Majors before Technology Application. The students' learning interaction in the class of architectural

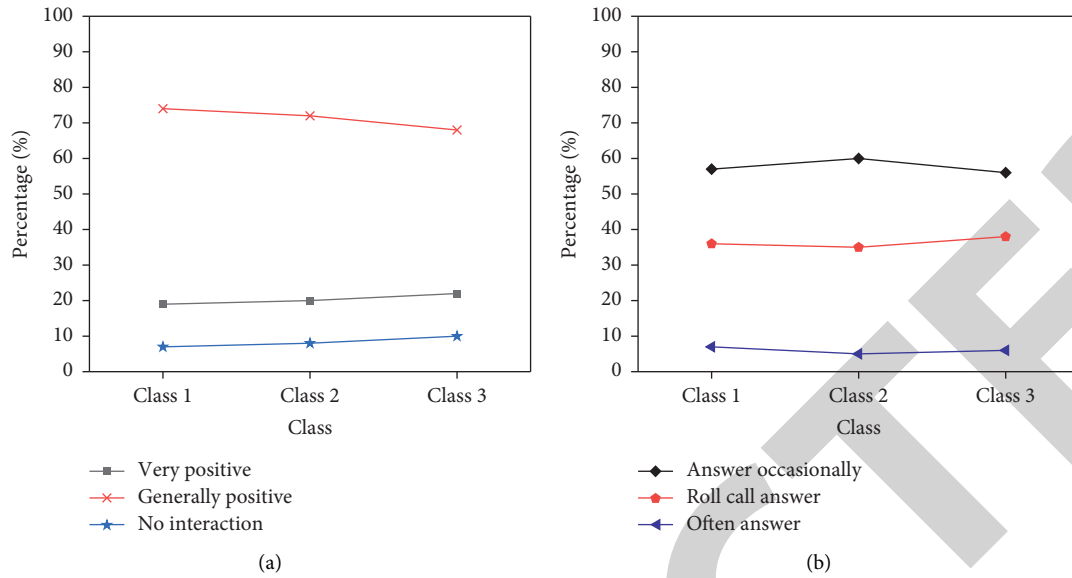


FIGURE 10: Classroom learning survey (a) Comparison of interaction enthusiasm; (b) Comparison of enthusiasm for answering questions.

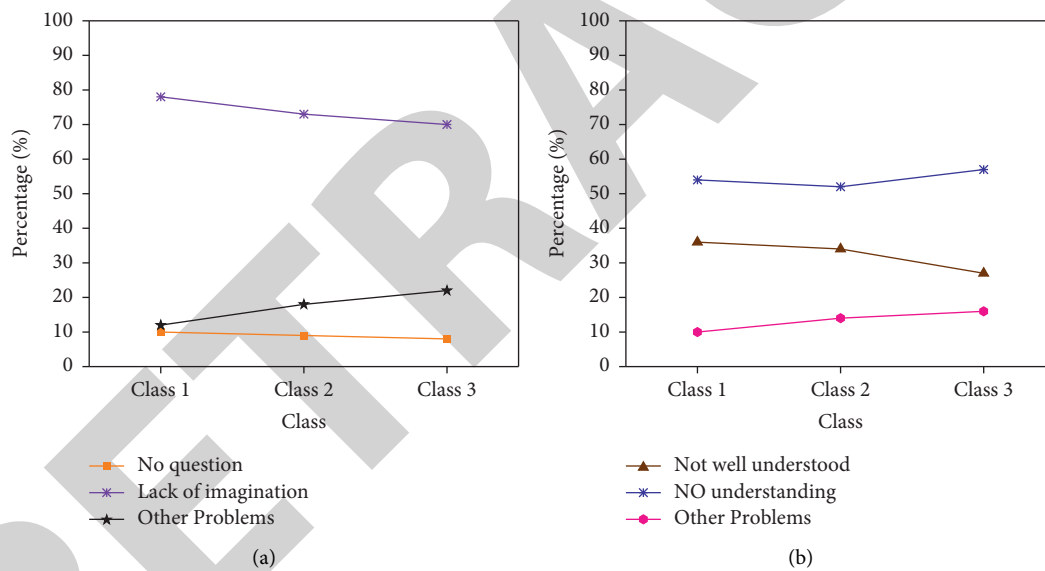


FIGURE 11: Survey of course understanding ability (a) Comparison of spatial imagination ability; (b) Comparison of drawing recognition ability.

project drawing and reading course is investigated, and the results are exhibited in Figure 10.

In terms of classroom interaction, more than 60% of the students show general enthusiasm. Less than 30% of the students have a less-frequent interaction. More than 20% of the students never interacted, and less than 30% presented positive interaction. More than 50% of the students only answer questions occasionally in terms of answering questions. The students who often answer questions account for 7% to the greatest extent. The rest of the students answer questions under the teacher’s roll call. On the whole, students’ classroom learning is still passive, and the classroom atmosphere lacks activity.

3.2.3. Analysis of Classroom Understanding Ability of Engineering Cost Budgeting Majors before Technology Application. Figure 11 compares students’ understanding ability in architectural project drawing and reading.

According to Figure 11, most students lack spatial imagination, and less than 10% of students have sufficient spatial imagination ability. Regarding drawing recognition, 36% of the students cannot understand the project drawings well, and over half cannot recognize or understand the drawings. Thus, most students have many thinking and drawing ability problems and lack practical training.

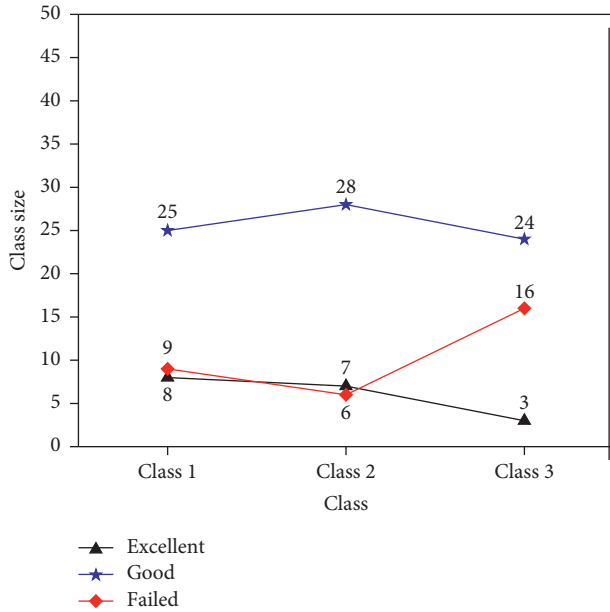


FIGURE 12: Classroom homework statistics.

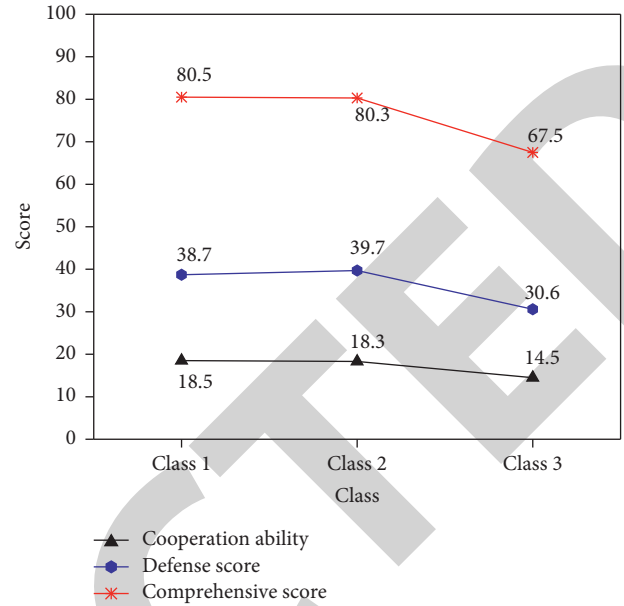


FIGURE 13: Assessment of course knowledge map defense.

### 3.3. Investigation and Analysis of Course Teaching Based on BIM and VR Technology

**3.3.1. Analysis of the Completion of Classroom Homework.** In the research after technological application, BIM and VR technology are used to teach engineering cost budgeting Class 1 and Class 2, called experimental classes. For comparison, a control class, Class 3, continues to adopt the traditional teaching model. Figure 12 unfolds the survey results of students' homework completion.

According to Figure 12, in experimental Class 1 and Class 2, more students have excellent and good homework performance than in the control class, and the gap is obvious. Meanwhile, students from the experimental classes are less likely to fail than those in the control class. Thus, the proposed teaching mode integrating BIM and VR technology can stimulate students' learning enthusiasm. It improves students' homework quality and academic performance and promotes teaching and learning.

**3.3.2. Analysis of Professional Map Reading Assessment.** This section trains students to read professional map reading using the predesigned assessment scheme and conducts map reading and defense assessment by professional teachers. The teacher assessment scores are spotted in Figure 13.

From the training and defense in Figure 13, students in the experimental class perform well in the practice of map reading skills. Thanks to the application of the BIM model in teaching, students can intuitively feel the characteristics of building structure in an all-around way. The proposed teaching model gives full play to the advantages of strong communication and cooperation ability of construction vocational students in terms of cooperation ability. The experimental class's defense and comprehensive scores are

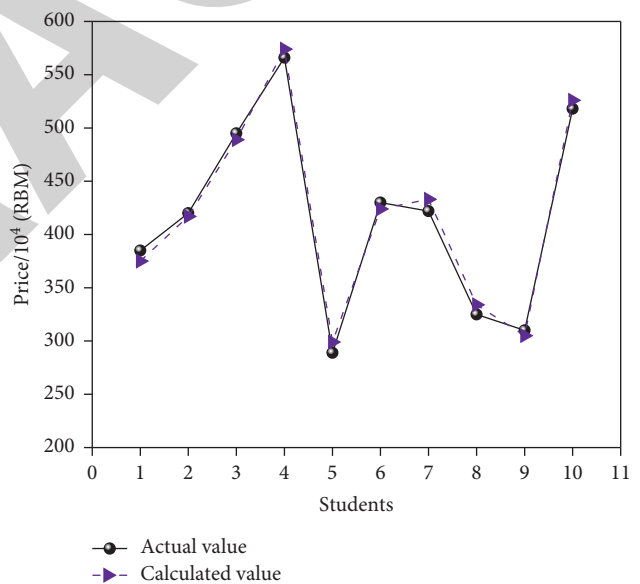


FIGURE 14: Engineering cost budgeting.

significantly higher than those of the ordinary class. Thus, integrating VR and BIM Technology can promote the teaching effect of engineering cost budgeting majors.

**3.4. Investigation and Analysis of BPNN Model in Course Teaching.** In order to verify the effectiveness and generalizability of the proposed BPNN-based ECE model, it is applied to practical teaching in engineering cost budgeting. Students' calculations of the comprehensive unit price using the BPNN model are comparatively analyzed with the real value. The results are displayed in Figure 14.

According to Figure 14, individual students' calculation results differ from the real comprehensive unit price.

However, overall, the students' prediction is accurate. Thus, the BPNN-based ECE model has high accuracy in the engineering cost budgeting and can be applied in practical teaching.

#### 4. Conclusion

First, this work introduces the BPNN to implement the ECE model. Then, it trains and tests the model with actual samples, estimates the total quotation and comprehensive unit price of the project, and analyzes the error between the real and the model-predicted value. Second, BIM and VR technology are integrated into teaching engineering cost budgeting to reform the traditional teaching model. The effects of classroom teaching on engineering cost budgeting majors are evaluated before and after using BIM and VR technology. The results show that (1) the fitting curve of total quotation and comprehensive unit price under the BPNN-based ECE model is very close to the training value. Thus, BPNN can be applied to the process of engineering cost budgeting. (2) The relative error between the model-predicted output and the real value can be controlled within a certain range. Hence, the proposed BPNN-based ECE model has good estimation ability and the potential to replace manual budgeting. (3) Most students passively learn and lack initiative in the traditional teaching model. Most students lack learning ability and practice ability in the classroom. (4) Classroom teaching integrating BIM and VR technology can improve students' homework quality and academic performance to a certain extent and promote teaching. (5) Classroom teaching integrating BIM and VR technology can enhance students' communication and cooperation ability, improve their defense scores and comprehensive scores, and promote teaching to a certain extent. (6) BPNN technology has high accuracy in the engineering cost budgeting and can be applied to practical teaching.

#### Data Availability

All data are fully available without restriction.

#### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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