Comprehensive Evaluation of Experimental Teaching Quality Using AHP-TOPSIS Technique

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Abstract—The key of university experimental teaching is to help students gradually perfect from knowledge learning to improvement of actual operational ability through experiments in the teaching and learning process. University experimental teaching is conducive for promoting innovative thinking and ability of practice of university students, and it plays an important role in the entire talent training system. Establishing scientific and reasonable evaluation methods and reflecting shortages in practical experimental teaching are not only keys of evaluation but also important guarantee to improve university experimental teaching quality. In this study, an evaluation index system of experimental teaching quality was constructed by combining analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS). Weights of indexes were determined. Moreover, a case study based on a comprehensive evaluation of experimental teaching quality of Construction Engineering CAD for civil engineering majors of undergraduates was performed. Results demonstrated that Level 2 indexes about teachers' good preparation of lessons and complete and standard teaching documents (X-1-3), as well as students' active thinking and positive participation in classroom learning (X-3-2), had the highest weight. Students' evaluation ranking results provided quantitative references to more scientific evaluation of experimental teaching. The comprehensive evaluation of experimental teaching quality using AHP-TOPSIS technique solves the mutual dependence and feedback relationship among evaluation indexes effectively, and avoids influences of subjectivity and one-sidedness of artificial weighting. Research conclusions can provide important references to optimize experimental teaching process, train the innovation ability of students, increase the comprehensive quality of students, and deepen reform in experimental teaching.

Keywords—AHP-TOPSIS, university experiment, experimental teaching, teaching quality, comprehensive evaluation

1 Introduction

Colleges and universities are cradle for training excellent talents. Teaching quality directly determines China's talent quality in the future. The teacher team level and the academic performance of students in universities can reflect teaching quality directly, and they determine the development of universities. Improving the quality of higher engineering educational has become a primary task of universities at present. Experimental teaching quality is reflected by university teaching level to a considerably large extent. Establishing a set of reasonable and effective experimental teaching quality evaluation system and reflecting problems in experimental teaching process reasonably are crucial. For engineering students, experimental teaching has been attracting increasing attention of educators due to its unique role in training students' innovative thinking and ability of practice. However, the evaluation system of university experimental teaching quality of engineering courses is still imperfect, and some subjects have not even formed an evaluation system of experimental teaching quality, thereby restricting the improvement of experimental teaching quality to some extent. For theory teaching, many engineering universities and colleges in China have established a set of relatively complete evaluation and monitoring system of theory teaching quality. However, no comprehensive evaluation system and method of experimental teaching quality according to experimental teaching characteristics has been established yet.

Experimental teaching is the key to train students' ability of practice. As an important link of training high-quality innovative talents, experimental teaching plays an important role in higher education. The key of experimental teaching is to help students gradually perfect from knowledge learning to improvement of actual operational ability through experiments in the teaching and learning process. In experimental teaching, some students often have inexplicit experimental goals and lack of systematic guidance on experimental steps and process, as well as reasonable arrangement of experimental subjects. Moreover, contents of the experimental instruction cannot guide students in computer experiments. Therefore, experimental guidance has to be further improved. Experimental quality reflects students' mastering of experiments and the teaching level of experiment supervisors. Some universities have not updated their equipment since their initial investment and construction in the early stage. Hence, experimental apparatuses are backward, and experimental environments can no longer meet the experimental needs of students. Therefore, establishing a scientific and reasonable evaluation system of university experimental teaching quality of engineering courses and reflecting shortages in experimental teaching are the key of evaluation and important guarantee to improve university experimental teaching quality.

2 Literature review

University experimental teaching reform is the source power to promote experimental teaching, and laboratory construction must be guided by experimental teaching. Experimental teaching content and laboratory system reform are keys of experimental teaching reform in universities and colleges. On the basis of the establishment and implementation of the evaluation system of experimental teaching quality, solving difficult problems is beneficial. It not only can improve laboratory construction and experimental teaching level but also promote the deepening of experimental teaching reform. How to make more scientific comprehensive evaluation on university and experimental teaching quality mainly concentrates on aspects of optimizing comprehensive evaluation method, perfecting evaluation indexes, and using different research objects. Bacher-Hicks et al. [1] analyzed university experimental teaching quality by using three predictive validities to evaluate teacher performance, including value-added, classroom observation, and student survey. The results supported the teacher evaluation system of value-added and classroom observation. Qianna [2] believed that the intelligent evaluation of classroom teaching quality is a modern education development direction, and RVM has been improved based on the feature extraction of ACLLMD and empirical mode decomposition method; as a result, the author proposed an evaluation model of university experimental teaching quality. The accuracy and reliability of evaluation results were analyzed by test data. The study proved that the new method is feasible and reliable. The reliability of the algorithm was also verified by comparing it with artificial scoring results. The research results demonstrated that the classroom theoretical and experimental teaching quality evaluation model based on RVM model has high accuracy and good reliability. On the basis of the mixing technique of data mining and hidden Markov model, Zeng [3] evaluated sports teaching effect in universities comprehensively from the teaching ability of teachers and the learning effect of students. The research results provided beneficial exploration to the integration of computer technology and language teaching. Maulana et al. [4] evaluated the teaching quality of new teachers in three years before the recruitment, and found that the teaching quality perceived by students increased more quickly as time went on under experimental conditions. Mashburn et al. [5] analyzed a classroom video of experimental teaching in 20 min by using the observation method, and found that 20 min might be enough for evaluators to observe the real characteristics of teaching quality, which was evaluated by the used measurement method in this study. Naumann et al. [6] believed that teaching sensitivity is a psychological measuring ability to test or capture single classroom teaching effect. According to the analysis on quasi-experiment intervention research data of science education to 1026 students in primary schools, the results showed that the sensitivity measurement of items might be related to practical classroom teaching. Spooren et al. [7] constructed a tool with 31 items, including the 10-point Likert scale. On the basis of education theory and empirical data, the results emphasized the value of scale technology in student assessment of teachers' performance. Douglas and Douglas [8] conducted a semi-structured interview of employees from a business college in the UK, thereby acquiring existing studies and major data. According to the survey results, the faculty members all had extremely low confidence on the feedback questionnaire of students, and the authors suggested to optimize the questionnaire design when evaluating teaching quality based on questionnaires. Dunrong and Fan [9] believed that teaching evaluation is a basic system to guarantee teaching quality in universities. The authors suggested to establish an accurate student evaluation view of teaching quality, build a scientific student evaluation system of teaching quality, and perfect the student evaluation system of teaching quality and the teaching quality guarantee system in Chinese universities and colleges. On the basis of the exploratory factor analysis method, Zerihun et al. [10] designed the student evaluation of learning and teaching questionnaire, which covers four factors, including evaluation and feedback, course organization and lecture, self-evaluation of students, and engagement degree of students. The results showed that students could evaluate teaching according to their own learning progresses by using a questionnaire measuring approach. Feistauer and Richter [11] evaluated lectures and seminars in recent three years through a standardized evaluation questionnaire. The results demonstrated that individual perceptions of students to teaching and the consistency between these perceptions and specific teaching influenced their evaluation significantly. Byrne and Flood [12] argued that course experience questionnaire (CEQ) has been used to measure the teaching quality of degree courses. They analyzed the reliability of this questionnaire in the background of Ireland and its structural validity in the accounting subject. Chen et al. [13] demonstrated that paying close attention to teachers and their teaching process can improve the teaching quality of higher education, except for organization concern or outcome-oriented short-term evaluation. Goos and Salomons [14] evaluated more than 3000 courses in a university in Europe, and found that student evaluation bias of teaching quality is mainly caused by the selection of unobserved features. Through an interview of teachers and managers, Maslow and Kelley [15] explored how teachers and schools use information in teaching evaluation and thus promoted teaching practices through formative and systematic feedback. The results showed that the effectiveness of teacher evaluation, as a learning tool, is determined by more extensive school environment and culture, as well as the degree that school leaders use evaluation as a meaningful tool of teacher and organizational learning. Hammonds et al. [16] reported that the student evaluation on teaching method can record and improve teaching quality, and acquiring practical information from teaching practice courses to the maximum extent is critical to improve the evaluation of experimental teaching quality. Ingvarson and Rowe [17] emphasized the importance of teacher quality (mainly including teacher qualification, experiences, and student use of academic achievements) in improving the academic performance of students and education experiences of schools. Hallinger [18] analyzed student evaluation data of courses, which were collected in 21 semesters in 7 years. The results revealed that some correlation exists between the good teaching performance of teachers and the high academic performance of students. Cadez et al. [19] reviewed the relationship between research performance and teaching quality, and found that research productivity is unrelated to teaching quality, whereas research quality is positively related to teaching quality. According to existing studies, the experimental teaching process generally includes philosophy of experimental teaching, method and mean, experimental teaching project, and content arrangement. Various problems in experimental teaching process can be discovered easily through the evaluation system of experimental teaching quality. These problems can be overcome by changing the education thought, correcting the teaching attitude, updating the experimental teaching content, and improving the experimental technologies. Hence, implementing the experimental evaluation system is beneficial to optimize the experimental teaching process, train the innovation ability students, and improve the comprehensive quality of students. In this study, the advantages of analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) were combined. The former has strong advantages and extremely suitable to solve evaluation-related problems. The latter can solve the shortages of AHP in evaluation, and provides an opportunity to establish and analyze the multi-quantity evaluation index system. Finally, results have positive significance to the comprehensive evaluation of university experimental teaching quality.

3 Methodology

3.1 Brief introduction of models

AHP solves practical problems, and hierarchical structure is generally composed of three layers, namely, target, criterion, and measurement layer. In the hierarchical structure with complicated relations, group relations are not obvious sometimes. In other words, several elements of the previous layer control several elements of the next layer at the same time, thereby forming cross-hierarchical relations. However, the subordinate relationship between the previous layer and the next layer shall be explicit, no matter how complicated the hierarchical relations are. First, the judgment matrix should be easy to construct according to hierarchical structure, and each element with downward membership (called as criterion) is used as the first element (upper-left corner) of the judgment matrix. All elements affiliated to the first element are arranged at the first row and the first column behind it, which can be expressed as follows:

$$A=(a_{ij})=\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \tag{1}$$

where n refers to the number of factors in the current layer, which are related with the criterion of the previous layer; and a_{ij} denotes the fuzzy scale. Next, the elements of each row of the matrix A were multiplied, and the n squares were calculated, as shown as follows:

$$w_i^* = \sqrt[n]{\prod_{j=1}^{n} a_{ij}},\ i=1,2,\dots,n \tag{2}$$

The weight w_i is calculated as

$$w_i = \frac{w_i^*}{\sum_{i=1}^{n} w_i^*},\ i=1,2,\dots,n \tag{3}$$

Next, the sum of the indexes in each column of the matrix A is calculated as follows:

$$s_j = \sum_{i=1}^{n} a_{ij},\ j=1,2,\dots,n \tag{4}$$

$\lambda_{\max}$ is calculated as

$$\lambda_{\max} = \sum_{i=1}^{n} w_i s_i \tag{5}$$

The characteristic root of the judgment matrix *A* was solved, and the eigenvectors *W* were gained. These eigenvectors became the ranking weight of attributes after normalization. A consistency check is needed to avoid errors in weights, and the results of the judgment matrix should conform to reality. The specific formula of the consistency index (CI) is

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \tag{6}$$

where *n* is the number of orders of the judgment matrix *A*. The values of the mean random CI of orders 1–9 of the judgment matrix are listed in Table 1.

Table 1. Mean random CI of orders 1–9 of the judgment matrix

Order Number of the Matrix	1	2	3	4	5	6	7	8	9
CI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

When the judgment matrix conforms to the CI, the weight vectors of the hierarchical factors could be calculated. TOPSIS is a distance-based comprehensive evaluation approach. It is characteristic of the schematic ranking of "ideal solution" and "negative ideal solution" based on multi-objective decision-making problem. The ideal solution or negative ideal solution is an optimal or the worst scheme, which is imagined in the original data matrix after normalization. Next, the distances of a scheme to the optimal and the worst schemes are calculated, which discloses the similarity of the scheme with the optimal scheme. The evaluation results are ranked according to similarity. Through common trending and normalization of the original data, the TOPSIS method eliminates the influences of dimensions of different indexes, and it can reflect real distance among schemes objectively; thus, it has been widely applied. First, suppose there exists *m* targets (finite) and *n* attributes. If the expert evaluation value of the *j*th attribute of the *i*th target is x_{ij}, the initial judgment matrix *V* is in formal (7).

$$V = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{7}$$

However, *V* has to be normalized because different indexes might have different dimensions to obtain the judgment matrix V'. Hence, Eq. (8) is acquired.

$$V' = \begin{bmatrix} x'_{11} & x'_{12} & \cdots & x'_{1n} \\ x'_{21} & x'_{22} & \cdots & x'_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x'_{i1} & \cdots & x'_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ x'_{m1} & x'_{m2} & \cdots & x'_{mn} \end{bmatrix} \tag{8}$$

where

$$x'_{ij} = x_{ij} / \sqrt{\sum_{k=1}^{n} x_{ij}^2}, i = 1,2\ldots m; j = 1,2\ldots n \tag{9}$$

Next, the attribute information weight matrix of the expert group (B) was acquired according to AHP, thereby forming the weighted judgment matrix (Z), as shown as follows:

$$Z = V'B = \begin{bmatrix} x'_{11} & x'_{12} & \cdots & x'_{1n} \\ x'_{21} & x'_{22} & \cdots & x'_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x'_{i1} & \cdots & x'_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ x'_{m1} & x'_{m2} & \cdots & x'_{mn} \end{bmatrix} \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_{i1} & \cdots & w_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ w_{m1} & w_{m2} & \cdots & w_{mn} \end{bmatrix} = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ f_{i1} & \cdots & f_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{bmatrix} \tag{10}$$

According to the weighted judgment matrix, the positive ideal solution (f_j^*) and negative ideal solution (f'_j) of the evaluation objective were acquired, as shown as follows:

$$f_j^* = \begin{cases} \max(f_{ij}), j \in J^* \\ \min(f_{ij}), j \in J' \end{cases}, j = 1,2,...,n$$
$$f'_j = \begin{cases} \min(f_{ij}), j \in J^* \\ \max(f_{ij}), j \in J' \end{cases}, j = 1,2,...,n \tag{11}$$

where J^* is a benefit-based index, and J' is a cost-based index. The Euclidean distance between the target and ideal values is calculated as

$$S_i^* = \sqrt{\sum_{j=1}^{m} (f_{ij} - f_j^*)^2}, j = 1,2,...,n$$
$$S'_i = \sqrt{\sum_{j=1}^{m} (f_{ij} - f'_j)^2}, j = 1,2,...,n \tag{12}$$

Finally, the relative closeness (C_i^*) of targets is calculated as

$$C_i^* = \frac{S_i'}{S_i^* + S_i'} i = 1, 2, ..., m \tag{13}$$

According to target ranking based on C_i^*, decision-making references were formed.

3.2 Index system

China's Ministry of Education is promoting the construction of the experimental teaching demonstration center and views it as an important component of quality engineering. A set of index system has been proposed to national experimental teaching quality. Hence, the status of comprehensive teaching quality evaluation was investigated based on this standard system through questionnaire survey, expert interview, and other methods. Finally, a comprehensive evaluation index system of university experimental teaching quality was formed in Table 2.

Table 2. Comprehensive evaluation index system of experimental teaching quality

Level 1 Indexes	Contents of Level 2 Indexes	Index No.
Teaching content	Clear teaching objectives, and scientific and reasonable teaching contents	X-1-1
	Teaching contents are deep and broad	X-1-2
	Teachers prepare lessons fully, and teaching documents are complete and standard	X-1-3
Teaching method	Teach students in accordance of their aptitudes, and teaching is enlightening	X-2-1
	Reasonable blackboard-writing and multimedia design	X-2-2
	Using appropriate learning modes positively	X-2-3
Teaching effect	Students complete the learning objective well	X-3-1
	Students have active thinking and participate in classroom learning positively	X-3-2
	Teaching style is prominent, and teaching mode is novel	X-3-3
Teaching reflection	Elaborate the teaching design idea of the lesson clearly	X-4-1
	Self-evaluation and improvement positively after class	X-4-2
	After-class teacher evaluation on experimental operation of students	X-4-3
	Classmates can give positive mutual evaluations	X-4-4

3.3 Data source

Zhejiang Province, China is a region with developed higher education. E-commerce develops remarkably quickly in Zhejiang Province, and there exists a considerable annual yield. In this study, managers and teachers from the Office of Educational

Administration of Zhejiang University of Technology, Hangzhou Electronic Science and Technology University, China Jiliang University, Zhejiang Sci-Tech University, and Zhejiang Gongshang University were invited for the initial scoring of the index system, thereby obtaining the original matrix of the AHP. The weights of the 16 indexes were calculated. Subsequently, students who majored in civil engineering in the five universities were chosen as evaluation objects, and the course Construction Engineering CAD was used as the investigation course. Five students were chosen randomly from each university, and a total of 35 students were chosen to provide scores in a seven-point Likert scale in terms of 16 aspects of the comprehensive evaluation system of experimental teaching quality. On this basis, the original scores of the experimental teaching quality were acquired.

4 Results analysis

4.1 AHP results

After obtaining the original data for AHP, the AHP results in Tables 3 and 4 were calculated using Matlab2019b programming.

Table 3. Summary of consistency test results

Maximum Eigenvalues	CI	RI	CR	Consistency Check
3.009	0.005	0.52	0.009	Pass
3.000	0.000	0.52	0.000	Pass
3.009	0.005	0.52	0.009	Pass
4.145	0.048	0.89	0.054	Pass

As shown in Table 3, the CI value of the three-order judgment matrix was 0.000, and the RI value was 0.520 after table look-up. Hence, the calculated CR values were 0.009 and 0.000 (<0.1). The CI value of the four-order judgment matrix was 0.048, and the RI value was 0.890 after table look-up. Hence, the calculated CR value was 0.054 (<0.1). These results revealed that the judgment matrix in this study met the consistency check, and the calculated weights were consistent.

Table 4. AHP results of level 1 indexes

Items	Eigenvector	Weight	Maximum Eigenvalue	CI
Teaching content	0.933	23.327%	4.587	0.196
Teaching method	1.23	30.745%		
Teaching effect	0.933	23.327%		
Teaching reflection	0.904	22.601%		

Table 5. AHP results of level 2 indexes

Level 2 Indexes	Eigenvector	Weight	Maximum Eigenvalue	CI Value	Final Weight
X-1-1	0.491	16.38%	3.009	0.005	0.038
X-1-2	0.892	29.73%			0.069
X-1-3	1.617	53.90%			0.126
X-2-1	1.200	40.00%	3.000	0.000	0.123
X-2-2	1.200	40.00%			0.123
X-2-3	0.600	20.00%			0.061
X-3-1	0.491	16.38%	3.009	0.005	0.038
X-3-2	1.617	53.90%			0.126
X-3-3	0.892	29.73%			0.069
X-4-1	0.707	17.69%	4.145	0.048	0.040
X-4-2	1.676	41.90%			0.095
X-4-3	0.559	13.98%			0.032
X-4-4	1.058	26.44%			0.060

As shown in Table 5 that Level 2 indexes about teachers' good preparation of lessons and complete and standard teaching documents (X-1-3), as well as students' active thinking and positive participation in classroom learning (X-3-2), had the highest weight. The reason was mainly because teaching preparation was the core element of experimental teaching. With fuller preparations, teachers can form an integrated experimental teaching system that can adapt to innovative talent training needs. This system is conducive to explore knowledge potentials of students to the maximum extent, and helps students develop their creative thinking, train their innovative quality, and master innovative skills by integrating experimental teaching contents and optimizing the overall course structure. In addition, this system is composed of several closely related layers and can be deepened gradually. Moreover, the system encourages students to participate in experimental classroom learning positively, supports students to participate in scientific studies, strengthens practice teaching link, perfects teaching quality assurance system, and motivates the learning enthusiasm and initiatives of students fully.

4.2 TOPSIS results

TOPSIS ranks according to the distance of evaluation objects to positive and negative ideal solutions, which enables to make a relative quality evaluation. The evaluation indexes were initially determined, which assured that all evaluation indexes should have a positive trend simultaneously (a higher value is better). The calculated results are shown in Table 6.

Table 6. Positive and negative ideal solutions

Items	Positive Ideal Solution A+	Negative Ideal Solution A–
X-1-1	0.229	0.115
X-1-2	0.485	0.208
X-1-3	0.754	0.377
X-2-1	0.861	0.369
X-2-2	0.738	0.369
X-2-3	0.430	0.184
X-3-1	0.229	0.115
X-3-2	0.880	0.377
X-3-3	0.485	0.208
X-4-1	0.280	0.120
X-4-2	0.663	0.284
X-4-3	0.221	0.063
X-4-4	0.418	0.179

The positive and negative ideal solutions in Table 6 are the intermediate process values when calculating the positive and negative distances (D+ and D−), and they have relatively small significance. The positive ideal solution A+ refers to the maximum of evaluation indexes, whereas the negative ideal solution A− refers to the minimum of evaluation indexes.

Table 7. Calculated results of TOPSIS evaluation

Items	Distance to the Positive Ideal Solution D	Distance to the Negative Ideal Solution D−	Relative Similarity C	Ranking Results
object 1	0.336	0.903	0.729	7
object 2	0.197	1.023	0.838	1
object 3	0.263	0.915	0.777	3
object 4	0.946	0.261	0.216	32
object 5	0.714	0.441	0.382	26
object 6	0.808	0.327	0.288	30
object 7	0.650	0.545	0.456	23
object 8	0.414	0.785	0.655	11
object 9	0.827	0.383	0.317	28
object 10	0.701	0.478	0.406	25
object 11	0.558	0.594	0.516	17
object 12	0.561	0.588	0.512	18
object 13	0.521	0.615	0.541	15
object 14	0.951	0.247	0.206	33
object 15	0.270	0.907	0.770	5

(Continued)

Table 7. Calculated results of TOPSIS evaluation *(Continued)*

Items	Distance to the Positive Ideal Solution D	Distance to the Negative Ideal Solution D−	Relative Similarity C	Ranking Results
object 16	0.899	0.391	0.303	29
object 17	0.622	0.560	0.474	21
object 18	0.500	0.692	0.581	13
object 19	0.942	0.474	0.335	27
object 20	0.640	0.641	0.500	20
object 21	0.347	0.924	0.727	8
object 22	0.674	0.521	0.436	24
object 23	0.448	0.705	0.611	12
object 24	0.265	0.910	0.775	4
object 25	0.361	0.853	0.702	9
object 26	1.101	0.124	0.101	35
object 27	0.266	0.892	0.770	6
object 28	0.414	0.813	0.662	10
object 29	0.521	0.615	0.541	14
object 30	1.101	0.179	0.140	34
object 31	0.617	0.539	0.466	22
object 32	0.600	0.624	0.510	19
object 33	0.895	0.362	0.288	31
object 34	0.586	0.652	0.527	16
object 35	0.231	1.019	0.815	2

In Table 7, D+ and D− are the distances of the evaluation object to the positive and negative ideal solutions, respectively. C refers to the closeness between the evaluation objects and the optimal scheme. A higher value indicates that the scheme is closer to the optimal scheme. Evaluation Objects 2, 3, and 35 ranked the highest scores in experimental teaching quality evaluation. The reason might be because the three students made a full review and preparation of the experiment, and they could communicate with their classmates about experimental operation, thereby achieving good experimental outcomes. Moreover, teachers had more sufficient teaching experiences and more diversified teaching techniques, which resulted in better teaching outcomes. Stronger learning ability and better learning atmosphere resulted in higher evaluation of teaching quality. This result was manifested by the high completion of the learning goal, high degree of classroom activity, and good knowledge and skill mastery of students. A comprehensive evaluation model of university experimental teaching quality using AHP-TOPSIS technique was proposed. The index weights were determined by AHP, which not only overcame the mutual dependence and feedback relationship among the evaluation indexes effectively but also avoided the influences of subjectivity and one-sidedness of artificial weighting. The comprehensive evaluation of university experimental teaching quality using AHP-TOPSIS technique can help teaching laboratories to understand problems and gaps in construction, use and manage processes, and improve their experimental teaching level continuously. These benefits can provide managers decision-making theoretical references and a set of feasible evaluation tools in scientific planning, reasonable input, continuous construction, and development of laboratories. The comprehensive evaluation of university experimental teaching quality based on AHP-TOPSIS is superior for simple principle, easy understanding, and intuitive conclusions. It is an update and improvement using the AHP-TOPSIS technique, and it is an effective comprehensive evaluation method. It also provides new ideas and methods for evaluation in other fields.

5 Discussions

University experimental teaching is an important support and guarantee to train innovative thinking and practical ability of university students. Construction standards of national and provincial experimental teaching demonstration centers have promoted universities to re-understand and deepen the philosophy, orientation, system, and connotation of experimental teaching, and facilitate reform development and quality improvement of university experimental teaching strongly. Thus far, many studies have emphasized the hardware evaluation of laboratories in universities. As a result, studies have investigated evaluation indexes about the curriculum system, experimental team, teaching resource, open management, and operation mechanism. Innovative talent training in universities, which is a system project, must facilitate communication between theoretical and experimental teachers. An experimental teacher construction mechanism integrating communication and involving part-time and full-time teachers must be established. A comprehensive evaluation of experimental teaching quality should also be constructed to assure successful experimental teaching and talent training. Civil engineering is a traditional major. Particularly, civil engineering is updated relatively quickly as a response to the emerging civil construction technique. Hence, experimental teaching is an essential teaching mean. Moreover, the evaluation of experimental teaching quality is a multi-factor, multi-object, and multi-layer complicated process. In this study the weights of Level 2 evaluation indexes were calculated by AHP. Subsequently, the teaching quality evaluation system was established using TOPSIS from the aspects of teaching content, method, effect, and reflection. Moreover, an empirical study based on Construction Engineering CAD was performed. The method could consider various factors comprehensively from multiple layers, realize the objective evaluation of experimental teaching quality, and decrease artificial interference. The results were objective and reasonable, and provided references to control teaching quality. The results also lay foundations for the development and realization of experimental teaching quality evaluation system related with engineering majors, such as civil engineering.

6 Conclusions

Experimental teaching is an important component in university teaching. The evaluation of experimental teaching quality is one of the key problems in experimental teaching. In this study, AHP-TOPSIS technique is used. First, influencing indexes are divided into several layers, and their weights are determined by AHP. Second, a decision-making model for the comprehensive evaluation of university experimental teaching is constructed to make decisions and rank the comprehensive quality of experimental teaching. Some major conclusions could be drawn. (1) Level 2 indexes about teachers' good preparation of lessons and complete and standard teaching documents (X-1-3), as well as students' active thinking and positive participation in classroom learning (X-3-2), have the highest weight. (2) The comprehensive evaluation of experimental teaching quality based on AHP-TOPSIS is superior for simple principle, easy understanding, and intuitive conclusions. It is an update and improvement of TOPSIS evaluation, and an effective comprehensive evaluation approach. It provides new ideas and methods for evaluation in other fields. A set of complete, effective, and operable long-term evaluation and management systems of university experimental teaching quality applicable to various universities should be established in the future. Moreover, extensive studies on the application and promotion of the evaluation system in universities are still needed.

7 References

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