



Research on the Effectiveness of Blended English Teaching Model Based on Fuzzy Comprehensive Evaluation

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SUMMARY: *The study is oriented to three key groups: experts, students and teachers, constructs multivariate indicators, selects subjective and objective empowerment methods, and establishes a fuzzy comprehensive evaluation model of the effectiveness of the blended English teaching model. Seventy-eight experts, 61 students and 45 teachers are invited to conduct the fuzzy comprehensive evaluation. Taking a blended English classroom as the evaluation object, the students were most satisfied with the teaching effect, with an overall excellent affiliation of 0.638. The experts also highly recognized it, with an excellent and good affiliation of over 91%. Teachers were more cautious in their evaluations, with a slightly higher percentage of good (37.3%) than excellent (34.5%). The blended teaching model $V=\{\text{Excellent, Good, Moderate, Pass, Poor}\}=\{0.520, 0.302, 0.110, 0.053, 0.015\}$, with a weighted score of 87.65, which is in the category of "Excellent".*

KEYWORDS: *Fuzzy Comprehensive Evaluation; Blended English Teaching; Factor Analysis; Hierarchical Analysis; Game Theory; Combined Empowerment*

1 Introduction

The quick development of IT technologies as well as new educational theories has led to the creation of blended learning, which has increasingly shown the advantages and promising applications in English teaching [1]. Blended learning combines face-to-face classroom learning and online learning, and thus maintains all the essential features of traditional learning while making use of the potentiality of online learning, giving new life to college English learning [2, 3].

The efficiency of the introduction of blended teaching in college English education is revealed through various aspects and can be measured by means of fuzzy comprehensive evaluation. First, blended teaching provides a large amount of various educational materials. Conventional modes of education are often faced with such problems as lack of materials and restrictions in regard to teaching content, whereas online education allows learners to have access to a large number of learning resources, such as online classes, ebooks, and video presentations [4, 5]. The provision of such materials expands the range of learning options and provides greater flexibility in applying them [6]. Regarding the benefits of blended learning for the resource provision, it should be noted that the application of blended teaching in English education is consistent with innovations in pedagogy and helps students learn English thanks to the availability of various resources and innovative approaches [7]. Literature [8] explores the benefits of using the blended teaching model in resource delivery, noting that given the

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prevalence of e-learning, the use of a blended approach involving both online and offline approaches is essential to provide the learner with sufficient teaching resources in the form of image, video, animation, and audio files. Literature [9] explores the positive impacts of “Internet Plus” in the education field, emphasizing the superiority of the blended teaching model in resource delivery and methodology. Literature [10] provides a systematic discussion of the blended learning model and stresses that its adoption will help in the incorporation of various types of resources and methodologies, which would motivate the learner. Literature [11] demonstrates that the application of the blended teaching model in English language teaching can enhance the level of involvement in the learning process, concluding from the survey findings that the adoption of this model can lead to the availability of ample teaching resources. Literature [12] emphasizes the advantages of the blended teaching model, especially in terms of easy access to learning materials, interactive activities, assessment and communication tools, and discusses the impact of the blended teaching model on teaching effectiveness.

Further, the integration teaching mode helps ensure efficient distribution and allocation of teaching resources, leading to better use of teaching resources on a broader scale [13]. Literature [14] argues that blended teaching plays an important role in promoting balanced educational development by ensuring improved transfer and sharing of educational resources, which would help equalize educational differences across various geographic locations. To solve the inefficiency problem in the existing methods of resource sharing, the literature [15] suggests a model of teaching resource sharing using a hybrid cloud computing teaching mode, whose efficiency is validated through results obtained.

At the same time, blended teaching helps enhance learning efficiency and promote learning engagement. Unlike traditional learning, which is dominated by the passive acquisition of information, the blended method of teaching promotes independent inquiry through online tools and class participation and discussions, thereby promoting a better comprehension and mastering of the English knowledge [16-19]. As for its role in stimulating learning interest, many researchers give positive reports. Research [20] focuses on the effect of blended teaching on students’ learning interest and motivation, and through the analysis of the survey results, finds out that the blended approach stimulates higher interest and motivation in learning, therefore, Recommend the wide application of this mode in pedagogy. Research [21] discusses how the design of instruction and the behaviors of learners affect the outcome of learning, and by applying the blended teaching method, finds out that the method promotes students’ learning interest and engagement, thus enhancing learning outcomes. Literature [22] states that the blended teaching approach uses the rich resources provided by the Internet and makes it possible to master subjects through different learning environments, thereby creating a favorable learning atmosphere and fostering students’ learning interests. Literature [23] focuses on the impact of blended teaching on class participation, taking into consideration the factors like interactivity of the course, instructional strategies used, and the comfortable learning environment in order to offer innovative insights into the design of classes and learner participation. Literature [24] ediscusses the function of blended teaching in promoting learner autonomy, and through the analysis of survey data, finds out that the mode promotes motivation, learning interest and engagement, and gains positive acceptance among learners.

Personalized learning is a key component of blended teaching, as it allows for the creation of personalized learning programs based on students' learning environments and preferences, thus allowing for personalized learning [25]. The literature on personalized learning in blended teaching includes research [26] on the use of blended teaching in higher education English classes, which found that such a technique had a major effect on instructional performance and personalizing instruction to address changing learning needs. One Literature [27] on the

blended learning model in times of the coronavirus pandemic found that the blended learning model was a productive instructional model in a period of crisis, helping students learn autonomously and meeting individualized needs. Another Literature [28] indicated that the blended learning model helped students become more engaged, autonomous, and successful learners by adopting personalized instructional techniques; however, there were also a number of issues associated with the model's adoption. Literature [29] created an adaptive catechism framework through enhanced blended learning models. It showed through empirical testing that such a framework would help personalize learning and provide supplementary training. Literature [30] provided a systematic introduction to the blended teaching model, its applications, impacts, and challenges. While highlighting the benefits of the blended teaching model in instruction, such as personalized learning, flexibility, and greater involvement, it also mentioned the issues involved, such as technological dependence and digital inequality.

For the assessment of the effectiveness of the blended English teaching model, the fuzzy comprehensive evaluation method can integrate online teaching resources, personalized teaching and other multiple factors to provide an objective and effective assessment, avoiding the reality of the traditional teaching evaluation methods, such as strong subjectivity and ambiguity.

From the perspectives of experts, students and teachers, the study screened 17 evaluation indexes initially set up in four dimensions, namely, teaching plan, method, attitude and classroom performance, and constructed a multilevel index system applicable to different evaluation subjects. At the same time, the innovative use of game theory based on the combination of empowerment method. Based on the factor analysis method of objective empowerment, based on the expert experience of the hierarchical analysis method of subjective empowerment, through a linear combination to find the optimal balance between the two, to establish the combination of evaluation index weights. Using the fuzzy comprehensive evaluation method for overall judgment, the obtained indicators and weights, combined with specific comments (such as excellent, good, medium), through multi-level fuzzy arithmetic, condensed into an intuitive comprehensive evaluation value.

2 The Construction of English Teaching Evaluation System and Comprehensive Evaluation Methods

2.1 Screening of evaluation index factors of blended English classroom

The evaluation indexes of blended English classroom teaching initially set up by the study are shown in Table 1, containing 17 indexes in four dimensions: teaching plan, teaching method, teaching attitude and classroom performance situation.

Table 1: The initially evaluation indicators for Blended English Teaching

Primary indicator	Secondary indicator
Teaching Plan	TP1: Scientific and reasonable classroom teaching
	TP2: Moderately adjust the teaching plan to ensure timely completion
	TP3: Set clear and measurable English teaching goals
	TP4: The connection and balance of teaching phases before, during, and after class
Teaching Methods	TM1: Use multimedia teaching for explanations
	TM2: Help students expand their English classroom learning horizons
	TM3: Teach meticulously, explain in simple terms, and provide many examples
	TM4: Focus on students' listening, speaking, reading, and writing abilities, achieving comprehensive improvement
Teaching Attitude	TA1: The teaching content in the English class should be fully prepared
	TA2: Strictly manage classroom discipline
	TA3: Provide timely feedback on students' questions
	TA4: Reasonably arrange class time, be on time for class, and avoid early departures
Class performance	CP1: Clarity of English oral expression
	CP2: The proportion of Chinese and English in oral communication
	CP3: The approximate proportion of new words in oral communication
	CP4: The degree of students' enthusiasm in answering questions
	CP5: The ratio of oral Chinese and English when students answer questions

The above evaluation indicators were screened at three levels: expert, student and teacher, respectively. The scoring of the appropriateness of the assessment of each indicator provides for a scoring specification from 1 to 4 (4-extremely critical, 3-not critical, 2-critical, extremely uncritical-1).

2.1.1 Expert evaluation indicator screening

The expert level consists of 120 experts such as front-line teachers, directors of teaching and research, and English language practitioners, etc. The statistics of the expert evaluation research on the initial 17 indicators are shown in Figure 1.

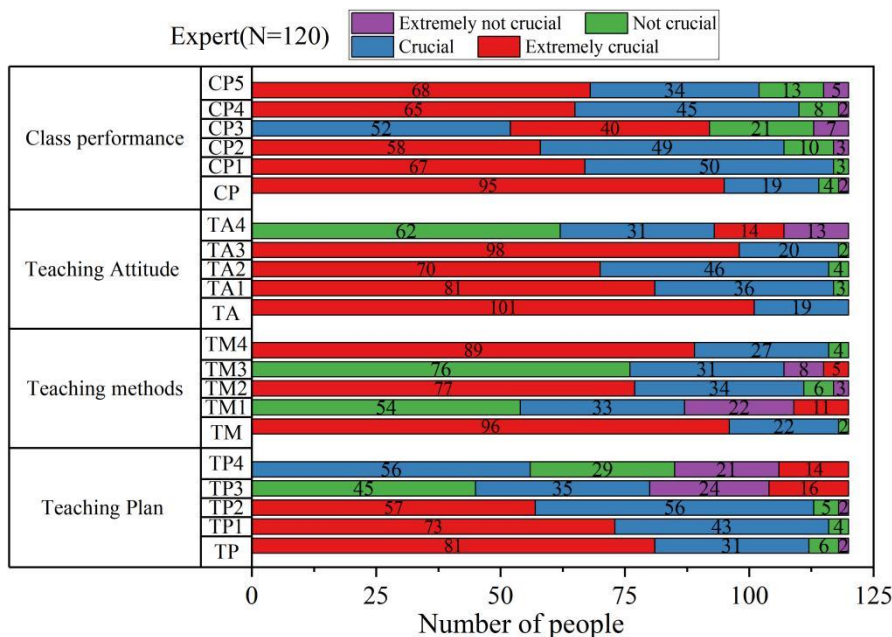


Figure 1: Experts' statistics on the evaluation indicators for English classes

Expert evaluation focused on the systematic, scientific and standardized nature of teaching. Among the teaching plans, TP3 Timely Completion of Teaching Plans and TP4 Balance of Teaching Sections were only recognized by 51 and 70 experts, with disapproval rates of 57.5% and 41.7%, so they were excluded. Among the teaching methods, TM1 Multimedia teaching and TM3 Teaching examples have a low affirmation rate, 76 and 84 experts think they are not critical respectively, so they are also excluded. As for teaching attitude, the indicator of TA4 not arriving late and leaving early had an approval rate of only 36.7% and was deleted. In classroom performance, the five indicators were 97.5%, 89.2%, 76.7%, 91.7% and 85.0% respectively in terms of the percentage of affirmation, and CP3 Oral Vocabulary was slightly lower but still higher than 75%, which was retained for the time being after deliberation. The final expert evaluation system containing 4 primary indicators and 12 secondary indicators is shown in Table 2.

Table 2: English teaching evaluation system under expert level

Primary indicator	Secondary indicator
Teaching Plan	Scientific and reasonable classroom teaching
	Moderately adjust the teaching plan to ensure timely completion
Teaching Methods	Help students expand their horizons in English classroom teaching
	Pay attention to students' listening, speaking, reading and writing abilities, achieving comprehensive improvement
Teaching Attitude	The teaching content in the English class should be fully prepared
	Strictly manage classroom discipline
	Provide timely feedback on students' questions
Class performance	Clarity of English oral expression
	The proportion of Chinese and English in oral language
	The approximate proportion of new words in oral language
	The degree of students' enthusiasm in answering questions
	The ratio of oral responses in Chinese and English when students answer questions

2.1.2 Screening of student evaluation indicators

The student level mainly researches 250 college students, scores the suitability of each index according to the above rules, 243 questionnaires are recovered, and the final student evaluation research statistics are shown in Figure 2.

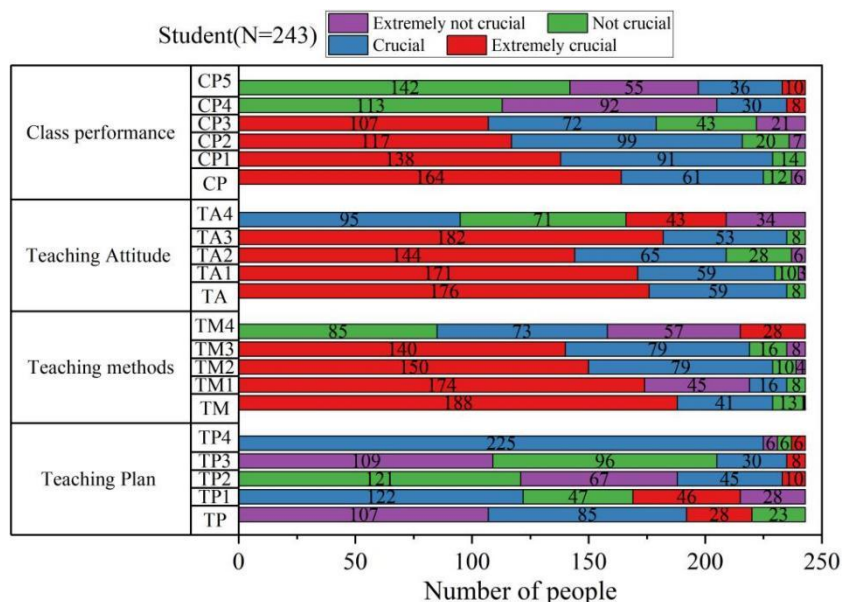


Figure 2: Students' statistics on the evaluation indicators for English classes

Student evaluations pay more attention to the interactivity, practicality and classroom experience of the teaching process. Based on the data in Figure 2, the percentage of “extremely critical + critical” was calculated, and the percentage of indicators higher than 70% was retained. The overall proportion of teaching programs is low, and the recognition rate is only $(28+85)/243=46.52\%$, so all of them are excluded. In teaching methods, TM1 (190/243), TM2 (229/243) and TM3 (219/243) were above the threshold, and TM4 not being late and leaving early had only 41.6% approval, so it was excluded. Among the teaching attitudes, TA4's ability to listen, read and write was only 56.8%, excluded. In classroom performance, CP1 (94.2%), CP2 (88.9%), and CP3 (73.7%) were retained, and CP4 answering questions positively (15.6%) and CP5 oral ratio in English and Chinese (18.9%) were below the threshold and excluded. The final student evaluation system with three primary indicators and nine secondary indicators is shown in Table 3.

Table 3: English teaching evaluation system under student level

Primary indicator	Secondary indicator
Teaching Methods	Using multimedia teaching for explanations
	Helping students broaden their perspective in English classroom teaching
	The teaching is detailed, easy to understand, and uses many examples
Teaching Attitude	The teaching content in the English class should be fully prepared
	Strictly manage classroom discipline
	Timely feedback on students' questions
Class performance	The clarity of English oral language
	The proportion of Chinese and English in oral language
	The approximate proportion of new words in oral language

2.1.3 Screening of indicators for teacher evaluation

Teacher level research object for 69 front-line teaching college English teachers, the questionnaire recovery rate of 100%, get the teacher on the 17 + 4 indicators evaluation research statistics shown in Figure 3.

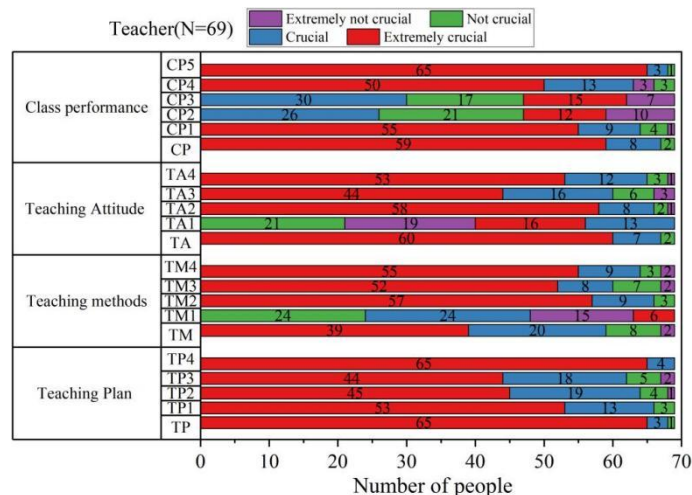


Figure 3: Teachers' statistics on the evaluation indicators for English classes

Teacher evaluations emphasized instructional goal attainment, classroom management, and student feedback. The percentage of affirmation for all indicators of the teaching program dimension was higher than 90%, and all of them were retained. In the teaching method dimension, TM2 (95.7%), TM3 (87.0%), and TM4 (92.8%) were retained, and TM1 multimedia teaching was recognized as $(6+24)/69=43.5% < 70%$, and was excluded. In the teaching attitude dimension, TA1 content preparation endorsement was 42.0%, which was generally considered by teachers as not critical and was excluded. In the classroom performance dimension, the number of endorsements for the percentage of English in CP2 speaking and the percentage of raw words in CP3 speaking were only 38 and 45, which were below the threshold, and were deleted. The final teacher evaluation system with 4 primary indicators and 13 secondary indicators is shown in Table 4.

Table 4: English teaching evaluation system under teacher level

Primary indicator	Secondary indicator
Teaching Plan	Scientific and reasonable classroom teaching
	Moderately adjust the teaching plan to ensure timely completion
	Set clear and measurable English teaching goals
	The connection and balance of teaching phases before, during, and after class
Teaching Methods	Help students expand their perspective on English classroom teaching
	Teaching should be detailed, easy to understand, and use many examples
	Pay attention to students' listening, speaking, reading and writing abilities, achieving comprehensive improvement
Teaching Attitude	The teaching content in the English class should be fully prepared
	Strictly manage classroom discipline
	Provide timely feedback on students' questions
Class performance	Clarity of English oral expression
	The enthusiasm of students in answering questions
	The ratio of students' oral responses in English and Chinese

2.2 Combinatorial Empowerment Method Based on Game Theory

In order to guarantee the comprehensiveness and reliability of the data, as well as the smoothness of data analysis, while taking into account both subjective empirical information and objective data information, and comprehensively utilizing the advantages of subjective and objective weighting methods, this study adopts the factor analysis and hierarchical analysis methods to calculate the evaluation indexes weights of the blended English classroom under the system of each perspective, and then calculates the optimal combination of weights based on the idea of game theory.

2.2.1 Objective Empowerment - Factor Analysis Method

Factor analysis (FA), also known as factor analysis, is a data analysis technique based on correlation that explores some hidden structure behind the data, looks for a set of common factors that explain most of the variation in the variables, combines factors that are essentially the same, and excludes those with minimal correlation, in order to reduce the number of variables, and also to test hypothesized relationships between variables. The factor analysis model uses a linear combination of factors to represent an observed variable, and the factor loadings are actually the weights of that linear combination. There are m evaluation objects, each object has k evaluation indicators, the original data sample is X_{ij} ($i = 1, 2, \dots, m; j = 1, 2, \dots, k$), and f_1, f_2, \dots, f_n ($n < m$) denotes the common factor of the extracted n ones, and any factor f_n to k variables can be linearly regressed. The linear regression of the individual variables can be expressed as:

$$X_i = \lambda_{i1}F_1 + \lambda_{i2}F_2 + \dots + \lambda_{in}F_n \quad (1)$$

where λ_{in} is the loading value of the i th indicator on the n th common factor f_n , and F_n denotes the component score of the n th common factor f_n . After establishing the factor analysis model, the factor loading matrix is obtained through parameter estimation, and the component scores of the public factors are calculated by regression method, as shown in equation (2).

$$F_n = \sum_{j=1}^k b_{ij}X_j \quad (2)$$

In equation (2), F_n denotes the component scores of the n th public factor, b_{ij} is the component coefficient of the j th variable on the i th component, and X_j denotes the loading value of the j th indicator.

Finally, the composite score value of each indicator, i.e., the weight ω_i , is calculated as shown in equation (3) below, and δ_{in} denotes the variance contribution ratio of the i th factor:

$$\omega_i = \sum_{n=1}^n \delta_{in}F_n \quad (n < m) \quad (3)$$

2.2.2 Subjective Empowerment - Hierarchical Approach

Hierarchical analysis (AHP) is a decision analysis method that combines qualitative and quantitative data. Hierarchical analysis breaks down the decision-making process into several

levels, and the decision maker only needs to compare the indicators within the levels two by two, and give a score according to the scoring criteria. The advantage is that less data is needed, the operation process is simple, no complex mathematical calculations are needed, and the results are easy to grasp and accept. The disadvantage is that this is a subjective empirical assignment, the results of the decision maker subjective influence. The general operation steps are:

(1) Establish a hierarchical model

Decision-making problem hierarchical processing, the establishment of hierarchical structure model, the first layer of the target layer, refers to the problem to be solved; the second layer of the guidelines layer, said to achieve the overall goal of the measures taken and programs, including the realization of the goal involved in the intermediate links, generally composed of a number of levels; the bottom layer for the program layer, said to solve the problem of the alternative options, or decision-making object.

(2) Construction of judgment matrix

The source of data for the hierarchical analysis is the judgment matrix formed by the expert group's two-by-two comparison of the scores of the factors at the criterion level, which is based on the degree of influence of the factors at the criterion level on the target level. Each expert according to experience in accordance with the 1-9 scale degree of importance of the indicators located in the same level of the hierarchy of a_i and a_j two indicators, through the method of two-by-two comparison, the scoring, and then based on the expert's comprehensive scoring to construct the judgment matrix.

(3) Judgment Matrix Consistency Test and Weight Calculation

Judgment matrix consistency test is to detect whether all the judgments in the matrix are consistent, consistency is a kind of transferability of judgments, such as the importance of a is two times of b , the importance of b is three times of c , then the importance of a is six times of c , or else it shows that the judgments are not consistent. However, in practice, due to the complexity of objective things and people's judgment of things when the comparison of fuzzy, it is difficult to get a completely consistent judgment matrix. Therefore, Saaty in the construction of hierarchical analysis, proposed a consistency test, allowing the judgment matrix has a certain range of inconsistency. The steps of the test are as follows:

- 1) Calculate the maximum eigenvalue λ_{\max} of the judgment matrix
- 2) Calculate the consistency index (CI)

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (4)$$

A $CI = 0$ indicates perfect consistency, and a larger CI indicates greater inconsistency.

- 3) Calculate the consistency ratio:

$$CR = \frac{CI}{RI} \quad (5)$$

where RI represents the random consistency index, the corresponding RI value can be found by querying the RI table based on the hierarchy n .

(4) Judgment: when the consistency ratio $CR < 0.1$, the judgment matrix has satisfactory consistency; $CR > 0.1$, the judgment matrix needs to be adjusted for the next calculation.

The weight calculation of hierarchical analysis is divided into hierarchical single sorting and hierarchical total sorting, hierarchical single sorting that is, the calculation of the weight of each factor in the criterion layer, usually using the characteristic root method to derive the

relative sorting weight of the elements under a single criterion from the judgment matrix. The basic idea of the feature root method is that when the judgment matrix is a consistency matrix ($CR < 0.1$), the feature vector corresponding to the largest feature root λ_{\max} of the judgment matrix, after normalization (so that the sum of the elements in the vector is equal to 1) is the ranking weight vector w_i . Hierarchical total ranking is used to make the final decision by calculating the synthetic weights of the elements of each layer on the goal (i.e., the weights of the elements of the scheme layer) from the top to the bottom in order to achieve the final goal (goal layer). In this study, the method is only utilized to calculate the weights of the indicators in the criterion layer, and it is not necessary to make a decision, so only the hierarchical but sorting operation is carried out, and the scheme layer is two teacher trainees at random (it is tested that the scheme layer has no effect on the weights of the criterion layer). Hierarchical single sorting calculation process is as follows:

1) Judgment matrix column vector normalization

$$\tilde{w}_{ij} = a_{ij} / \sum_{i=1}^n a_{ij} \quad (6)$$

2) \tilde{w}_{ij} Summing by rows

$$\tilde{w}_i = \sum_{j=1}^n \tilde{w}_{ij} \quad (7)$$

3) Normalization

$$w_i = \tilde{w}_i / \sum_{i=1}^n \tilde{w}_i \quad (8)$$

$W_i = (w_1, w_2, \dots, w_n)^T$, i.e., the approximate feature root (weight vector).

2.2.3 Combinatorial Empowerment - Based on Game Theory Ideas

According to the basic idea of combinatorial assignment in game theory, assuming that there is L method to assign weights to the indicators respectively and get L kinds of indicator weights, any weight set is recorded as $W_k = \{\omega_1, \omega_2, \dots, \omega_k\} (k=1, 2, \dots, L)$, then any linear combination of L kinds of weight sets can be expressed as:

$$\omega_o = \sum_{k=1}^L \beta_k \omega_k^T (\beta_k > 0) \quad (9)$$

In Eq. (9), ω_o is the combination weight, L denotes the total number of sets with combination weights, k is the stacking coefficient, β_k denotes the combination coefficient of the k th class of weights, and ω_k denotes the set of weight vectors of the k th class. Drawing on the equilibrium idea of game theory, finding the most satisfactory weight vector ω_o can be reduced to optimizing the linear combination of vectors in Eq. (9), so that the sum of the extreme differences between the optimal weight vector ω_o and all other ω_k is

extremely small, see Eq. (10), where ω_g denotes the set of weights computed by the g th method.

$$\min_g \left\| \sum_{k=1}^L \beta_k \omega_k^T - \omega_g \right\|_2 \quad (10)$$

According to the nature of matrix differentiation, solve the optimal combination coefficient β_k , i.e., solve the system of linear equations in equation (11). The solved optimal combination coefficient β_k is normalized and substituted into Eq. (9) to calculate the evaluation index combination weight ω_o .

$$\begin{bmatrix} \omega_1 \omega_1^T & \omega_1 \omega_2^T & \cdots & \omega_1 \omega_L^T \\ \omega_2 \omega_1^T & \omega_2 \omega_2^T & \cdots & \omega_2 \omega_L^T \\ \vdots & \vdots & \cdots & \vdots \\ \omega_L \omega_1^T & \omega_L \omega_2^T & \cdots & \omega_L \omega_L^T \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_L \end{bmatrix} = \begin{bmatrix} \omega_1 \omega_1^T \\ \omega_2 \omega_2^T \\ \vdots \\ \omega_L \omega_L^T \end{bmatrix} \quad (11)$$

2.3 Fuzzy integrated evaluation method

On the basis of obtaining the weights of the indicators, the study utilizes the fuzzy comprehensive evaluation method to make a multidimensional and multilevel overall judgment on the effectiveness of blended English teaching.

2.3.1 Concept of fuzzy evaluation method

Fuzzy comprehensive judgment method is a scientific evaluation method that seeks clarity and precision in the ambiguity of objective things, which is different from the quantitative method and the qualitative method.

Fuzzy judgment is also called fuzzy evaluation, fuzzy review or fuzzy decision-making. That is, fuzzy mathematics is introduced into the judgment decision-making process. This is of great importance for a deeper and more accurate understanding to grasp the nature of the system. Because the success and failure of classroom teaching is the comprehensive effect of a variety of factors, with uncertainty and ambiguity, it is one-sided if only one kind of indicator is used to measure. And the evaluation of any teacher is often not good or bad distinctly, and people's evaluation of things mostly use vague language, therefore, the fuzzy evaluation better reflect the essence of things.

Fuzzy comprehensive evaluation method is a method of using fuzzy mathematical methods, through the fuzzy mathematical comprehensive evaluation model to come up with a conclusion on the evaluation of the quality of teachers' classroom teaching. The key to its successful application lies in the correct specification of the domain of fuzzy judgment and the reasonable construction of the fuzzy judgment matrix.

2.3.2 Fuzzy evaluation procedure

(1) Establishment of a collection of evaluation phrases

$$V = \{V_1, V_2, V_3, \dots, V_n\} \quad (12)$$

$V_n (n = 1, 2, 3 \dots m)$ is the evaluation grade from high to low.

In this paper, the evaluation grade of each factor in each layer is divided into five grades: excellent, good, moderate, pass, and poor, so the set of evaluation results $V = \{\text{Excellent, Good, Average, Fair, Poor}\} = \{V_1, V_2, V_3, V_4, V_5\}$.

(2) Establish the indicator factor set of evaluation object

$$U = \{u_1, u_2 \cdots u_n\} \quad (13)$$

The element $u_n (n=1, 2 \cdots m)$ is a variety of main factors affecting the evaluated object, and u_n can be subdivided into evaluation sub-factor sets according to the actuality, which comprehensively reflect the evaluated object.

For example, taking the teaching indicator system at the expert level as an example, an evaluation group consisting of n English experts evaluates the 12 three-level indicators of a teacher's English classroom teaching evaluation, and determines the fuzzy evaluation set by using fuzzy statistics, assuming that the number of people in the evaluation group who evaluate a certain factor u_n as excellent, good, moderate, acceptable, or poor is q_1, q_2, q_3, q_4, q_5 respectively, then the fuzzy evaluation set of the factor is:

$$R_i = \left\{ \frac{q_1}{n}, \frac{q_2}{n}, \frac{q_3}{n}, \frac{q_4}{n}, \frac{q_5}{n} \right\} = \{r_{i1}, r_{i2}, r_{i3}, r_{i4}, r_{i5}\} \quad (14)$$

Then the set of one-factor evaluations for the first level factor U is:

$$R = \begin{pmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ r_{n1} & r_{n2} & r_{n3} & r_{n4} & r_{n5} \end{pmatrix} \quad (15)$$

(3) Determine the set of evaluation weights

$$A = \{a_1, a_2, \cdots a_n\} \quad (16)$$

Usually the influence of each element relative to the evaluation object is not the same, set the appropriate weights.

(4) First-level fuzzy evaluation

Choose the appropriate operator to synthesize the weight vector A and matrix R to get the fuzzy comprehensive evaluation model B .

$$\begin{aligned}
 B &= A \cdot R = (a_1, a_2, \dots, a_n) \cdot \begin{pmatrix} r_{11} & r_{12} & r_{13} & \dots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \dots & r_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ r_{n1} & r_{n2} & r_{n3} & r_{n4} & r_{nm} \end{pmatrix} \\
 &= (b_1, b_2, \dots, b_n)
 \end{aligned}
 \tag{17}$$

(5) Second-level fuzzy evaluation

The comprehensive evaluation matrix \bar{R} consists of B_i as row vectors, the

$$\bar{R} = \begin{pmatrix} B_1 \\ B_2 \\ \cdot \\ \cdot \\ \cdot \\ B_j \end{pmatrix}
 \tag{18}$$

Then the indicator weights W and \bar{R} are synthesized to produce the second-level comprehensive evaluation vector

$$U = W \cdot \bar{R} = (u_1, u_2, \dots, u_n)
 \tag{19}$$

Then U is normalized to obtain \bar{U} .

(6) Synthesize the evaluation results

$$Q = \bar{U} \cdot V
 \tag{20}$$

where $V = (5, 4, 3, 2, 1)^T$ and the composite evaluation value is calculated.

3 Determination of evaluation indicator weights

3.1 Objective empowerment based on factor analysis

3.1.1 Factor analysis

First, based on the expert approach index system of combined English teaching, the 12 indexes were analyzed through factor analysis. Three major factors were selected according to the condition that the value of $\lambda > 1$, resulting in a variance contribution rate of 90.677%. The results are shown in Table 5.

Table 5: Eigenvalues and cumulative contribution rate

Factor	Initial eigenvalue			Extracted sum of squares loaded			Rotated sum of squares loaded		
	Total	Variance/ %	Cumulative/ %	Total	Variance/ %	Cumulative/ %	Total	Variance/ %	Cumulative/ %
1	17.758	62.218	62.218	17.758	62.218	62.218	16.571	60.094	60.094
2	8.512	20.377	82.595	8.512	20.377	82.595	7.187	18.115	78.209
3	1.751	8.082	90.677	1.751	8.082	90.677	3.806	12.468	90.677
4	0.916	3.159	93.836						
5	0.734	2.072	95.908						
6	0.667	1.597	97.505						
7	0.545	0.994	98.499						
8	0.494	0.727	99.226						
9	0.354	0.384	99.61						
10	0.231	0.184	99.794						
11	0.123	0.128	99.922						
12	0.075	0.078	100						

The three factors contributed 62.218%, 20.377% and 8.082% respectively, with a cumulative variance contribution of 90.677%. These three dimensions alone explain more than 90% of the information contained in the 12 indicators under the original expert perspective.

3.1.2 Factor loading matrices

Figure 4 shows the rotated factor loading matrix.

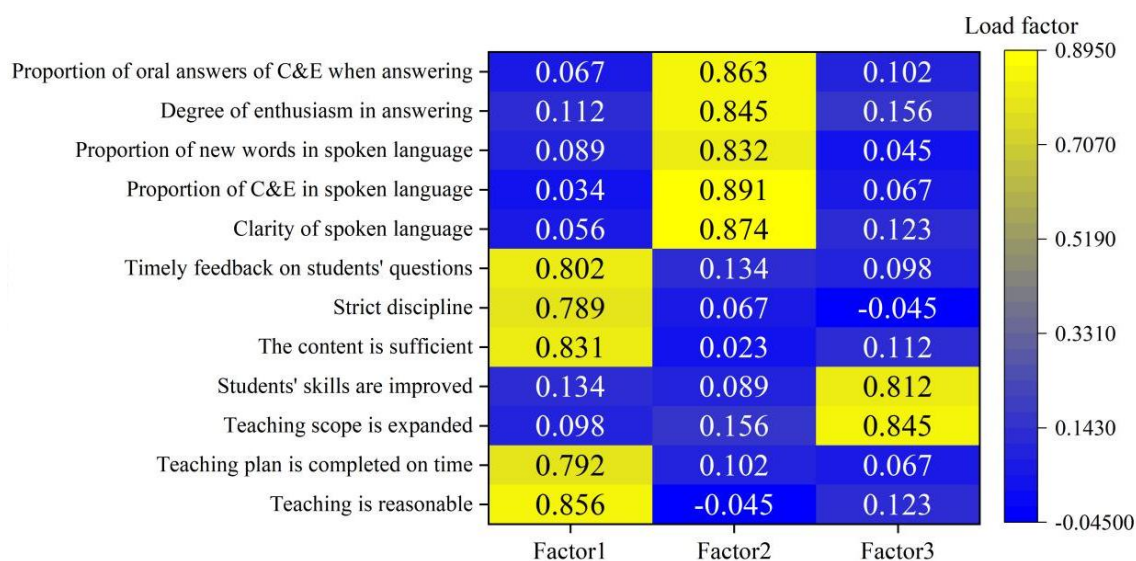


Figure 4: Rotated factor loading matrix

The first factor is mainly highly correlated with the indicators of teaching plan and teaching attitude, namely "scientific and reasonable classroom teaching", "moderate adjustment of teaching plan", "full preparation of teaching content", "strict management of classroom discipline" and "timely feedback on problems" (with coefficients of 0.856, 0.792, 0.831, 0.789 and 0.832 respectively). Summarize the first principal component as instructional design and process assurance. The second principal component is highly correlated with five indicators of classroom performance, and its load factor ranges from 0.832 to 0.891. The third principal component focuses on teaching methods and ability orientation, covering two indicators:

"Helping students broaden their classroom horizons" and "emphasizing the improvement of students' comprehensive abilities in listening, speaking, reading and writing", with correlation coefficients of 0.845 and 0.812 respectively.

3.1.3 Objective weighting

Based on the factor loading matrix, normalization was used to obtain the objective weights as shown in Table 6.

Table 6: The objective weight of the English teaching evaluation system of experts

Primary indicator	Weight	Secondary indicator	Weight
Teaching Plan	0.161	TP1	0.087
		TP2	0.074
Teaching Methods	0.166	TM1	0.087
		TM2	0.079
Teaching Attitude	0.233	TA1	0.082
		TA2	0.073
		TA3	0.078
Class performance	0.440	CP1	0.091
		CP2	0.093
		CP3	0.081
		CP4	0.087
		CP5	0.088

Based on the expert system the objective weights of each of the secondary indicators are more homogeneous, concentrating in a narrow range from 0.073 to 0.093, making the weights of the primary indicators {0.161,0.166,0.233,0.440}.

3.2 Subjective empowerment based on the hierarchical analysis approach

Based on the scoring criteria of 120 experts for each indicator in section 2.1.1 (Figure 1), the steps of hierarchical analysis in section 2.2.2 were followed step-by-step to derive the subjective weights under the experts' perspectives as shown in Table 7.

Table 7: The subjective weight of the English teaching evaluation system of experts

Primary indicator	Weight	Secondary indicator	Partial Weight	Overall weight
Teaching Plan	0.240	TP1	0.513	0.123
		TP2	0.487	0.117
Teaching Methods	0.253	TM1	0.489	0.124
		TM2	0.511	0.129
Teaching Attitude	0.257	TA1	0.332	0.085
		TA2	0.323	0.083
		TA3	0.345	0.089
Class performance	0.249	CP1	0.211	0.053
		CP2	0.200	0.050
		CP3	0.182	0.045
		CP4	0.206	0.051
		CP5	0.202	0.050

Based on Figure 1, it can be seen that the experts for the teaching program, teaching methods, teaching attitude and classroom performance of the four dimensions of the importance of the rating is almost the same (four appropriate degree scoring total score of 431, 454, 461 and 447, respectively), so the final four subjective weights were 0.240, 0.253, 0.257 and 0.249. The objective weights of the second-level indicators under each dimension are different. There is a clear expert bias in favor of classroom instruction in the instructional program (combined weight of 0.123).

3.3 Combinatorial Empowerment Based on Game Approach

3.3.1 Expert Evaluation System Portfolio Weights

The objective and subjective weights under this blended English teaching evaluation index system are obtained above by taking the expert perspective as an example, respectively. Now, based on formulas (9), (10) and (11), the optimal weight vector is obtained, and the two linear combining factors of the optimal weighted set are carried out to obtain the game combination weights of each indicator as shown in Table 8.

Table 8: Combined weights of evaluation indicators from the expert perspective

Primary indicator	Obj weight	Subj weight	Com weight	Secondary indicator	Obj weight	Subj weight	Com weight
Teaching Plan	0.161	0.240	0.200	TP1	0.087	0.123	0.105
				TP2	0.074	0.117	0.095
Teaching Methods	0.166	0.253	0.209	TM1	0.087	0.124	0.105
				TM2	0.079	0.129	0.104
Teaching Attitude	0.233	0.257	0.244	TA1	0.082	0.085	0.083
				TA2	0.073	0.083	0.078
				TA3	0.078	0.089	0.083
Class performance	0.440	0.249	0.344	CP1	0.091	0.053	0.072
				CP2	0.093	0.050	0.071
				CP3	0.081	0.045	0.063
				CP4	0.087	0.051	0.069
				CP5	0.088	0.050	0.069

Based on the game theory of combination assignment to seek the optimal compromise solution of minimizing differences, the combination weights of the four first-level indicators are $\{0.200, 0.209, 0.244, 0.344\}$, taking the classroom performance situation as an example, there is a huge divergence between its objective weight (0.440) and subjective weight (0.249), and the combination of the assignment achieves $W=0.344$, which is neither completely biased in favor of the importance of the data nor completely compliant with the subjective underestimation of experts, but to find the optimal middle balance point. The combination of weights achieves $W=0.344$, which is neither completely biased towards data importance nor completely compliant with subjective underestimation by experts, but finds the optimal intermediate balance.

3.3.2 Student evaluation system portfolio weights

Based on the blended English teaching evaluation index system established under the students' perspective in Table 3, which consists of three primary indicators and nine secondary indicators, its objective and subjective weights are derived respectively according to the steps mentioned

above, and then the combined weights are obtained based on the game method as shown in Table 9.

Table 9: Combined weights of evaluation indicators from the student perspective

Primary indicator	Obj weight	Subj weight	Com weight	Secondary indicator	Obj weight	Subj weight	Com weight
Teaching Methods	0.365	0.403	0.384	TM1	0.056	0.069	0.062
				TM2	0.162	0.123	0.143
				TM3	0.147	0.211	0.179
Teaching Attitude	0.360	0.231	0.296	TA1	0.136	0.052	0.094
				TA2	0.061	0.037	0.049
				TA3	0.163	0.142	0.153
Class performance	0.275	0.366	0.321	CP1	0.117	0.165	0.141
				CP2	0.086	0.104	0.095
				CP3	0.072	0.097	0.085

The students' focus is very different from the experts, and after the game integration, the combined weights of teaching methods, teaching attitude and classroom performance are {0.384,0.296,0.321}. Among the teaching methods with the highest weights, the secondary indicator TM3 “Teaching in detail, in-depth, more examples” has a weight of up to 0.179; the classroom performance of CP1 “clarity of spoken English” has a weight of W=0.141. The student group pursues learning experience and clear classroom gains more.

3.3.3 Teacher evaluation system portfolio weights

The blended English teaching evaluation index system (4 primary and 13 secondary indicators) based on Table 4 in the teacher's perspective is the same, and its objective, subjective and combined weights are shown in Table 10.

Table 10: Combined weights of evaluation indicators from the teacher perspective

Primary indicator	Obj weight	Subj weight	Com weight	Secondary indicator	Obj weight	Subj weight	Com weight
Teaching Plan	0.287	0.415	0.351	TP1	0.087	0.151	0.119
				TP2	0.073	0.085	0.079
				TP3	0.059	0.115	0.087
				TP4	0.068	0.064	0.066
Teaching Methods	0.263	0.247	0.255	TM1	0.104	0.087	0.096
				TM2	0.088	0.093	0.091
				TM3	0.071	0.067	0.069
Teaching Attitude	0.248	0.201	0.225	TA1	0.102	0.057	0.08
				TA2	0.057	0.032	0.045
				TA3	0.089	0.112	0.101
Class performance	0.202	0.137	0.169	CP1	0.08	0.054	0.067
				CP2	0.068	0.045	0.057
				CP3	0.054	0.038	0.046

The combined weights of the four first-level indicators under the teacher evaluation system were {0.351,0.255,0.225,0.169}, with instructional planning becoming the dimension with the highest combined weight, and teachers favoring classroom planning as the most fundamental

factor for instructional success. Among them, TP1 classroom science and rationality weighted 0.119. In contrast, teachers instead put classroom performance in the backseat.

4 Fuzzy Comprehensive Evaluation of English Blended Classroom

The indicators and weighting coefficients for assessing the quality of blended English teaching from different perspectives are established above. A blended English classroom is selected as the object of study, and the following assessment models are established by the fuzzy comprehensive judgment method for the expert assessment system, the student assessment system and the teacher assessment system respectively.

4.1 Classified fuzzy integrated evaluation

4.1.1 Expert evaluation system

Seventy-eight experts in the field of English language and teaching were invited to judge the blended English classroom based on the indicators in Table 2, and based on the evaluation result set $V = \{\text{Excellent, Good, Average, Fair, Poor}\} = \{V_1, V_2, V_3, V_4, V_5\}$, the evaluation matrix of the 78 experts for the indicators of the blended English classroom is shown in Figure 5.

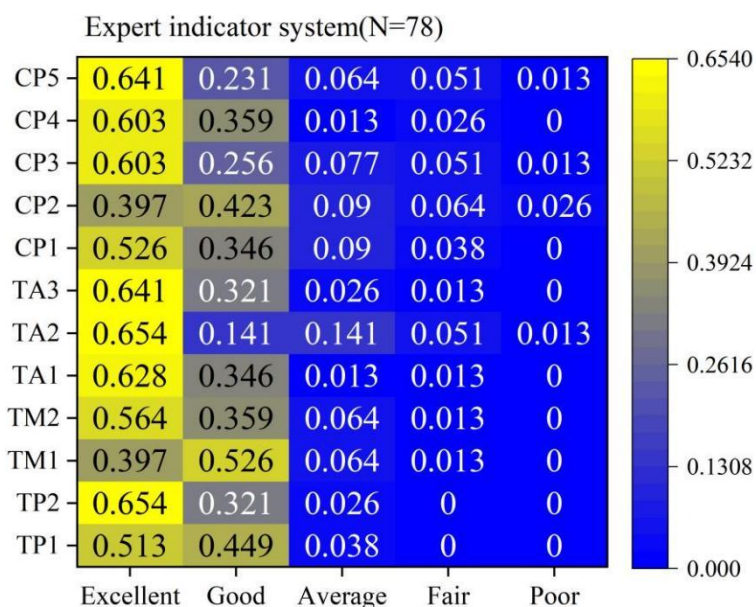


Figure 5: The experts' evaluation matrix for various indicators of the blended class

From Figure 5, we can see the evaluation results of the experts on the indicators of this blended English teaching, and then based on the combination weights of the indicators derived above $\{0.105, 0.095, 0.105, 0.104, 0.083, 0.078, 0.083, 0.072, 0.071, 0.063, 0.069, 0.069\}$, we get the overall expert $\{V_1, V_2, V_3, V_4, V_5\}$ evaluation results = $\{0.563, 0.348, 0.057, 0.025, 0.005\}$. That is, more than 56% of the evaluations tend to be V_1 -Excellent and nearly 35% V_2 -Good, and the total of the two is more than 91%, which indicates that the expert community highly recognizes the blended teaching model.

4.1.2 Student evaluation system

At the student level, 61 students who participated in this blended English teaching were invited to participate in the evaluation, and the students' evaluation matrix of the indicators of this blended English classroom is shown in Figure 6.

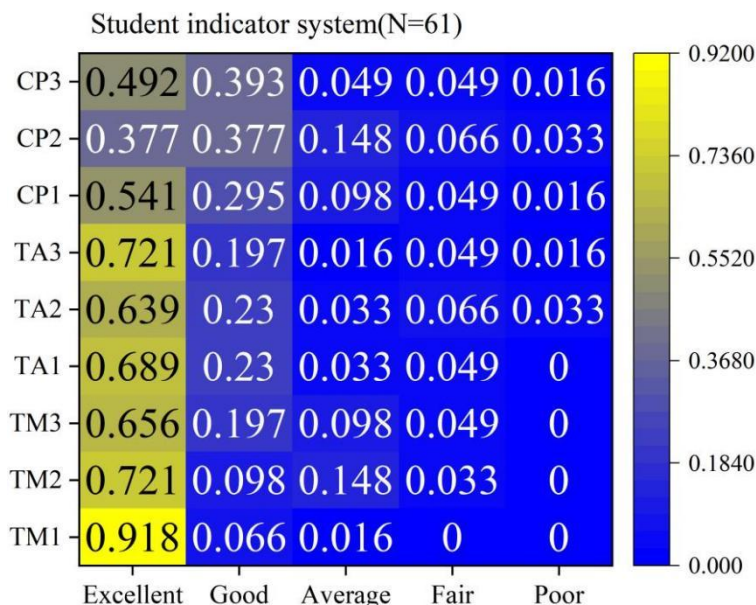


Figure 6: The students' evaluation matrix for various indicators of the blended class

The students' motivation for evaluation is also very high. Especially for the blended classroom TM1 utilizing multimedia, the ratio of V1 reaches 0.918, i.e., 56 out of 61 students were evaluated as “excellent”. Comparatively speaking, the evaluation of classroom performance is more discrete, for example, the ratio of CP2 spoken Chinese to English, the ratio of its five evaluations were 0.377, 0.377, 0.148, 0.066 and 0.033, but overall the ratio of excellent and good is more than 70%, which indicates that the students' feelings about the balance of language use in the blended classroom are more varied, but still mainly positive in general.

The secondary indicators of the student evaluation system are {0.062,0.143,0.179,0.094, 0.049,0.153,0.141,0.095,0.085}, and the overall evaluation result $U=\{0.638,0.227,0.079,0.046, 0.011\}$ is obtained. The degree of satisfaction with blended English classroom teaching from the students' point of view is slightly higher than that from the experts' point of view, with a degree of affiliation of 0.638 to “excellent”.

4.1.3 Teacher evaluation system

On the teacher side, 17 teachers who had participated in blended English teaching and 28 peer teachers in the traditional teaching mode were invited to evaluate the blended English classroom. The evaluation matrix of the indicators for the 45 teachers is shown in Figure 7.

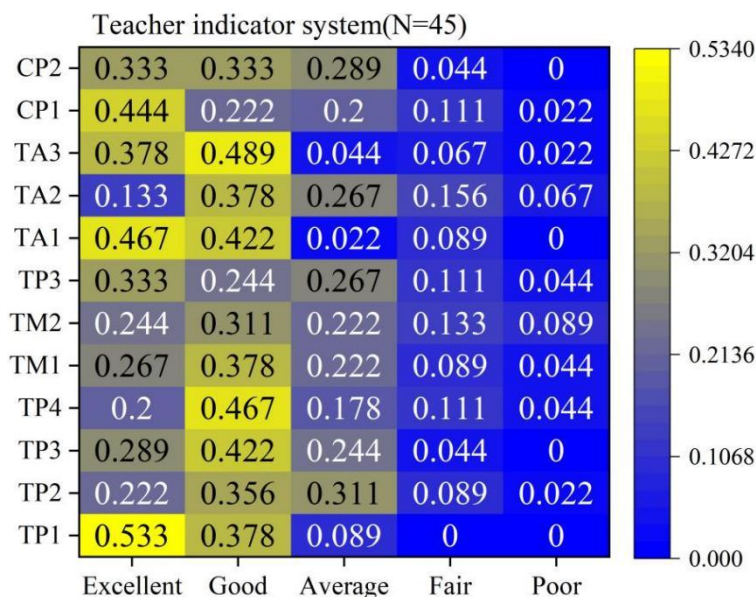


Figure 7: The teachers' evaluation matrix for various indicators of the blended class

Teachers were more cautious in their evaluations, but positive evaluations still dominated. Specifically, the teachers' V1 affiliation degree for the two indicators of TA1 content preparation and TP1 scientific rationality of teaching in blended classroom is 0.467 and 0.533 respectively, which means that 21 and 24 teachers out of 45 teachers gave excellent evaluations respectively. However, some of the indicators such as “TP2 Adjustment of teaching program” and “TA2 Management of discipline” were rated as unsatisfactory by 4 and 7 teachers respectively, with V4 affiliation of 0.089 and 0.133.

Based on the combined weights of the teacher evaluation system {0.119,0.079,0.087,0.066, 0.096,0.091,0.069,0.08,0.045,0.101,0.067,0.057,0.046}, the results of the 45 teacher names' evaluations for this blended ELT classroom were obtained as {0.345,0.373, 0.180,0.077,0.027}. Teachers' affiliation with “good” is greater, and even “moderate” is 0.180, indicating that the teacher group has a positive attitude towards blended learning as a whole, but their evaluation is more neutral, and they may have higher requirements and reservations about the details of the practice based on their own teaching experience. They may have higher requirements and reservations about the practical details based on their own teaching experience.

4.2 Three-level Fuzzy Comprehensive Evaluation of Blended English Teaching Models

In order to make a fair and reasonable evaluation of the teaching quality of English classroom, several expert teachers are invited to determine the weights of experts, students and teachers on the evaluation of the teaching quality of English classroom by combining the actual situation of English classroom in this university as (0.20, 0.45, 0.35).

From the results of the graded second-level fuzzy comprehensive evaluation in section 4.1, a single-factor matrix for the third-level fuzzy comprehensive evaluation is composed. If the weighted average model is selected, the three-level comprehensive judgment of a blended EFL classroom is derived as

$$\begin{aligned}
 B = A \cdot R &= (0.20, 0.45, 0.35) \cdot \begin{pmatrix} 0.563, 0.348, 0.057, 0.025, 0.005 \\ 0.638, 0.227, 0.079, 0.046, 0.011 \\ 0.345, 0.373, 0.180, 0.077, 0.027 \end{pmatrix} \\
 &= (0.520, 0.302, 0.110, 0.053, 0.015)
 \end{aligned} \tag{21}$$

Based on the maximum affiliation degree, it can be seen that the blended EFL classroom belongs to $V_1 = \text{Excellent}$ with an affiliation degree of 0.520, so the classroom belongs to the category of excellent.

Meanwhile, in order to make the conclusion more rigorous, the weighted average method is also used to quantify the rubric set. Let the rubric set volume index be $V\{\text{excellent, good, moderate, pass, poor}\} = \{95, 85, 75, 65, 55\}$. The weighted average method was utilized to find the score of this blended English classroom = 87.653, which is under the excellent category.

5 Conclusion

The study integrates the multiple perspectives of experts, students and teachers to analyze the effectiveness of the blended English teaching model. Based on game theory, the combination of weights is used to obtain balanced weights for each of the three perspectives, taking into account subjectivity and objectivity. In the expert system, the objective weight of classroom performance is 0.440, while the subjective weight is only 0.249, which is finally determined to be 0.344 after game integration. Meanwhile, students are the most active in this blended English classroom teaching. The fuzzy comprehensive evaluation shows that their membership degree to the "excellent" grade is as high as 0.638. Especially in the item of "Teaching with multimedia", the proportion of excellent reaches 91.8%. The distribution of expert evaluations is "excellent" with 0.563 and "good". At the teacher level, the evaluation is relatively strict and pragmatic, with the membership degrees of "excellent", "good" and "medium" being 0.345, 0.373 and 0.180 respectively. Based on the (0.20, 0.45, 0.35) weighting of the three levels, the final evaluation result of the blended English teaching classroom is 0.520 for "excellent", which confirms that blended English teaching is an effective model with both student satisfaction and professional recognition.

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