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Article

Research on the Application of Multi-Objective Decision Making Algorithm and Teaching Quality Improvement in Physical Education Teaching in Colleges and Universities

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Abstract: In this paper, in order to solve the multi-objective decision-making problem of teachers in physical education teaching, the weights of indicators at all levels in the hierarchical analysis method physical education teaching quality index system are introduced to be assigned. Then the fuzzy decision theory model is used to expand the one-dimensional decision-making of the fuzzy comprehensive evaluation model into multi-dimensional decision-making, to help college physical education teachers to complete the multi-objective decision-making of the teaching process and improve the quality of teaching. The results show that: in the fuzzy comprehensive evaluation index system of physical education constructed in this paper, the weight of the first-level index teaching process evaluation is the highest (0.4363), and the weight of the teaching background is the lowest (0.0611); among the second-level indexes, the top three indexes are the elements of the physical education curriculum, the organizational and systematic guarantee of the physical education teaching in the school and the overall performance of the teaching activities, and the comprehensive weights are 0.2015, 0.168 and 0.1409, respectively. 168 and 0.1409 respectively, and the weights of the rest of the indicators range from 0.0122 to 0.108, which shows that the importance of each indicator varies greatly. In addition, this paper summarizes nine group paths to improve the quality of physical education teaching, which can explain about 80% of the cases of physical education teaching quality improvement in colleges and universities.

Keywords: hierarchical analysis; fuzzy decision theory; fuzzy comprehensive evaluation; physical education teaching

1. Introduction

University physical education classes are not only an important component of the school education system but also an effective vehicle for enriching university sports and cultural activities [1]. With the progress of society and economic development, the content of physical education in Chinese universities has undergone continuous self-adjustment and reform. However, in today's reality, society, schools, and parents generally do not place a high priority on physical education [2-3]. The positioning of teaching objectives, as a key factor influencing teaching quality, is closely related to China's current talent cultivation model [4]. As quality education gains widespread acceptance, single-dimensional physical education teaching objectives no longer align with the practical needs of education in the new era. Facing this new landscape, how to scientifically define multi-objective decision-making in university physical education teaching and fully leverage the educational value of physical education has become an urgent priority for university physical education educators and an important issue for educational authorities to consider [5-7].

Scholars have conducted in-depth research on different physical education teaching models in higher education institutions. Literature [8] utilized multimedia feature extraction and three-dimensional human body reconstruction technology to evaluate the teaching effectiveness of university physical education courses. The results showed that compared to traditional methods, the teaching effectiveness under this model increased by 15.38% and also helped deepen understanding of abstract concepts. With the continuous innovation of teaching concepts, the flipped classroom teaching model has emerged as a new teaching method. Compared to traditional classrooms, it has both advantages and disadvantages. Literature [9] innovates teaching methods by applying Internet of Things (IoT) and machine learning technologies in the flipped classroom to enhance university physical education, thereby improving students' psychological training outcomes, theoretical proficiency, and academic performance. Literature [10] proposes and evaluates a novel blended teaching method for physical education during the COVID-19 pandemic, with results indicating that it is more effective in improving student academic performance compared to single-type teaching methods. Literature [11] explores the relationship between motor control theory and the learning process in physical education, while emphasizing the correspondence between these methods and various motor control models and learning strategies. In summary, there are many teaching models for physical education classes, and the emergence of different teaching models is aimed at improving teaching effectiveness [12-13]. With the continuous development of the times, all aspects of teaching have changed accordingly. Through the research of the above scholars, it can be concluded that a good classroom teaching model is the foundation for the rapid development of classroom teaching, and reasonable teaching content is indispensable for achieving teaching objectives [14].

This paper first introduces the principle of hierarchical analysis, and then through the construction of multilevel recursive structure, judgment matrix, to obtain the weight vector of indicators at all levels, to complete the process of applying hierarchical analysis in college sports teaching. Then with the help of the logical reasoning method of fuzzy teaching theory, a multilevel fuzzy decision-making model that can realize the comprehensive evaluation of teachers' teaching ability is constructed, and the solution algorithm under the condition of known target information is given. Finally, the application of the model in college physical education teaching and the effect of teaching quality improvement are analyzed.

2. Multi-Objective Fuzzy Decision-Making Model Based on Hierarchical Analysis

2.1. Hierarchical Analysis

2.1.1. Principles of Hierarchical Analysis

Hierarchical analysis method [15] through a system, a huge scale and contains a multi-level structure of the object for in-depth analysis, layer by layer decomposition, and ultimately form a multi-level, multi-dimensional target structure, the structure from shallow to deep can be divided into the target layer, guidelines and program layer, the final program layer includes a number of interlinked and interacting factors, through the comparison of the pair by pair, to quantify the relative importance of the elements of the various levels of the relative importance of the elements between, the use of Through pairwise comparison, the relative importance between the elements of each level is quantified and analyzed using mathematical methods such as linear algebra, and finally the total ranking of relative importance is carried out. It is a decision analysis method that combines qualitative analysis and quantitative calculation. The method is systematic, flexible, efficient and practical in project management.

2.1.2. Hierarchical Analysis Application Steps

Generally speaking, the use of hierarchical analysis should contain the following steps:

(1) Determine the research object

The use of hierarchical analysis should have a clear goal, first of all, you need to systematically analyze the goal to determine the depth of the evaluation of the research object should be achieved, according to the national and industry laws and regulations and other constraints to determine the scope of the research object. At the same time, the actual situation of the research object should be widely collected, and the supporting documents such as organizational structure, management process, financial data, technical data, etc. should be collected and arranged, and the authenticity and effectiveness of the data and materials should be ensured, so as to make sufficient preparation for the subsequent data analysis work.

(2) Constructing a multilevel step-by-step structural model

After determining the research object, through system analysis, seize the main influencing factors of the research object, analyze the research object layer by layer from coarse to fine, from shallow to deep, and form a multilevel step-by-step structure, which is usually divided into the target layer, the guideline layer, and the program layer. The objective layer is the goal or result that the system wants to achieve, and it is the primary criterion for system evaluation. The criterion layer is a smaller unit of objectives established to achieve the objective layer. The program layer, which can also be called the indicator layer, is the various programs and measures taken to achieve the objectives, and is the lowest level of indicators in the indicator system, which cannot be further subdivided. The indicators at the same level are interconnected and differentiated from each other, organically combined as a whole, logical and clear, hierarchical presentation of the whole picture of the evaluation object. The final structure of the hierarchical analysis method.

(3) Construct two-by-two comparison judgment matrix

After the construction of the multi-level indicator system is completed, it is necessary to use the experience and knowledge of experts to compare the indicators at each level two by two, to judge the relative importance of the sub-indicators under the same indicator, and thus to establish a judgment matrix. Taking the criterion level indicator $B_1 - B_n$ as an example, a_{ij} represents the ratio of the influence of elements B_i and B_j on the target A.

Construct a judgment matrix on a_{ij}:

$$A = (a_{ij})_{m\times n} = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \left(i = 1,2,3\cdots m, j = 1,2,3\cdots n \right) \tag{1}$$

where the elements in a are satisfied:

1) $a_{ij} > 0$

2) $a_{ij} = \dfrac{1}{a_{ji}}$, $i \neq j$

3) $a_{ij} = 1$, $i = 1,2\ldots n$

The a_{ij} denotes the value of the relative comparative importance of two relative influences. Saaty's 1-9 scale method is usually used to judge the criterion layer indicators two by two, different scales correspond to different degrees of relative importance, the larger the ratio, the higher the importance of i, and the qualitative judgments can be quantified by this step.

(4) Solve the weight vector

After obtaining the judgment matrix, according to the constructed judgment matrix, solve the weights of each index, there are two methods for calculating the weights: square root method and sum method.

The calculation steps of square root method:

1) Calculate the $\frac{1}{m}$ th power of the product of each row to get an m-dimensional vector:

$$\bar{\omega}_i = \sqrt[m]{\prod_{j=1}^{m} a_{ij}} \tag{2}$$

2) This vector is then normalized to get the weight vector:

$$\omega_i = \frac{\bar{\omega}_i}{\sum_{j=1}^{m} \bar{\omega}_j} \tag{3}$$

Calculate the weight vector $W = \left(W_1, W_2, \ldots, W_n\right)^T$.

And the calculation steps of the sum method are firstly to standardize each column of the judgment matrix, to sum the standardized elements by rows, and finally to standardize the sum result, the weight vector obtained is consistent with the weight vector obtained by the square root method.

(5) Solve the maximum characteristic root and consistency test

After obtaining the weight vector by the above method, the maximum characteristic root can be calculated:

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{W_i} \tag{4}$$

where n is the number of dimensions, i.e., the order of the judgment matrix, from which the consistency metric $C.I$ value can be further computed from the maximum eigenvalue $\lambda_{\max}$:

$$\text{C.I} = \frac{\lambda_{\max} - n}{n-1} \tag{5}$$

The role of consistency test is to test whether the constructed judgment matrix has logical problems. However, through the above formula, it is found that the larger the n, the larger the error in the value of $C.I$, so the randomness consistency ratio $C.R$ is introduced in the consistency test to reduce the impact of the error. I.e:

$$C.R = \frac{C.I}{R.I} \tag{6}$$

The stochastic consistency index obtained by Saaty simulation 1000 times. When the stochastic consistency ratio C. R < 0.1 it is considered that the calculated hierarchical ranking weights are correct and reasonable, otherwise the judgment matrix needs to be readjusted until the consistency test is qualified.

2.2. Multi-objective fuzzy decision-making model

The application of fuzzy decision theory [16] model expands the one-dimensional decision-making of the fuzzy comprehensive evaluation model to multi-dimensional decision-making.

Let the m evaluation index eigenvalues of the j th program be represented by a vector as $X_j = \{x_{1j}, x_{2j}, \cdots, x_{mj}\}^T$, and then the evaluation indexes of the n th program are represented by the index eigenvalue matrix as:

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} = (x_{ij})_{m\times n} \tag{7}$$

Where x_{ij} denotes the eigenvalue of the j th program, the i th indicator, $i = 1, 2, \cdots, m$; $j = 1, 2, \cdots, n$.

In order to eliminate the influence of scale and magnitude between m evaluation indicators, according to the fuzziness and relativity, the relative affiliation matrix is:

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} = (r_{ij})_{m\times n} \tag{8}$$

Where r_{ij} is the relative affiliation degree of x_{ij}, $0 \le r_{ij} \le 1$, $i = 1, 2, \cdots, m$; $j = 1, 2, \cdots, n$.

Fuzzy comprehensive evaluation is based on m evaluation indexes, and n programs are evaluated according to c standard evaluation models. Let the fuzzy comprehensive evaluation matrix be:

$$U = \begin{pmatrix} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ u_{m1} & u_{m2} & \cdots & u_{cn} \end{pmatrix} = (u_{hj})_{c\times n} \tag{9}$$

where u_{hj} denotes the degree of affiliation of evaluation j to the h th standard evaluation model, $h=1,2,\cdots,c$; $j=1,2,\cdots,n$.

Eq. (9) should satisfy $0 \le u_{hj} \le 1$, $\sum_{h=1}^{c} u_{hj} = 1$.

Let c standard evaluation model m indicator eigenvalues, expressed in standard indicator fuzzy matrix, be:

$$S = \begin{pmatrix} s_{11} & s_{12} & \cdots & s_{1c} \\ s_{21} & s_{22} & \cdots & s_{2c} \\ \cdots & \cdots & \cdots & \cdots \\ s_{m1} & s_{m2} & \cdots & s_{mc} \end{pmatrix} = (s_{ih})_{m\times c} \tag{10}$$

Where s_{ih} denotes the relative affiliation of the i th indicator of the h th standard evaluation model, $i=1,2,\cdots,m$; $h=1,2,\cdots,c$.

Let the m evaluation indicators of the evaluation program have different degrees of contribution to the evaluation results, and the vector of indicator weights is:

$$W = \left\{w_1, w_2, \cdots, w_m\right\}^T, \sum_{i=1}^{m} w_i = 1 \tag{11}$$

The relative affiliation values of the j indicators of the evaluation program are expressed as fuzzy vectors:

$$r_j = \left\{r_{1j}, r_{2j}, \cdots, r_{mj}\right\}^T \tag{12}$$

The relative affiliation values of the h indicators of the standardized evaluation scheme are expressed as fuzzy vectors:

$$h_j = \left\{h_{1j}, h_{2j}, \cdots, h_{mj}\right\}^T \tag{13}$$

The difference between the evaluation scheme j and the standard evaluation scheme h is expressed as a weighted distance (p is the distance parameter, generally taken as $p=1$ or $p=2$):

$$d_{jh} = \sqrt[p]{\sum_{i=1}^{m} \left[w_i (r_{ij} - s_{ih}) \right]^p} \tag{14}$$

Let the affiliation degree of program j to the standard evaluation h be u_{hj}, in order to more comprehensively measure the difference between the evaluation program j and the standard evaluation h, the affiliation degree is used as a weight to obtain the generalized weighted distance of the difference between the evaluation program j and the standard evaluation program h:

$$D_{jh} = u_{hj} \sqrt[p]{\sum_{i=1}^{m} \left[w_i (r_{ij} - s_{ih}) \right]^p} \tag{15}$$

Create an objective function:

$$\min \left\{ F(u_{hj}) = (1-\alpha) \sum_{j=1}^{n} \sum_{h=1}^{c} \left[u_{hj} \sqrt[p]{\sum_{i=1}^{m} \left(w_i (r_{ij} - s_{ih}) \right)^p} \right]^2 + \alpha \sum_{j=1}^{n} \sum_{h=1}^{c} \left[\sqrt[p]{\sum_{i=1}^{m} \left(w_i (r_{ij} - s_{ih}) \right)^p} \right]^2 \right\} \tag{16}$$

Taking $p=2$ and assuming that the relative affiliation matrix R, the standard fuzzy evaluation matrix S and the weight vector W are known, solve for the optimal affiliation matrix U of the evaluation scheme. The above equation becomes:

$$\min\left\{L(u_{hj},\lambda)=(1-\alpha)\sum_{j=1}^{n}\sum_{h=1}^{c}\left[u_{hj}^{2}\sum_{i=1}^{m}\left(w_i(r_{ij}-s_{ih})\right)^2\right]\right.$$
$$\left.+\alpha\sum_{j=1}^{n}\sum_{h=1}^{c}\sum_{i=1}^{m}\left[w_i(r_{ij}-s_{ih})\right]^2-\lambda\left(\sum_{h=1}^{c}u_{hj}-1\right)\right\} \tag{17}$$

Derive equation (17) and make the derivative zero:

$$\frac{d_L(u_{hj},\lambda)}{du_{hj}}=2(1-\alpha)u_{hj}\sum_{i=1}^{m}\left[w_i(r_{ij}-s_{ih})\right]^2-\lambda=0 \tag{18}$$

$$\frac{d_L(u_{hj},\lambda)}{d\lambda}=\sum_{h=1}^{c}u_{hj}-1=0 \tag{19}$$

Equations (18) and (19) are collapsed to give:

$$u_{hj}=\frac{1}{\sum_{k=1}^{c}\frac{\sum_{i=1}^{m}\left[w_i(r_{ij}-s_{ik})\right]^2}{\sum_{i=1}^{m}\left[w_i(r_{ij}-s_{ih})\right]^2}} \tag{20}$$

Let $\left(r_{hj}^{i}\right)=\left(u_{hj}^{(i)}\right)$, then:

$$R_i=\begin{pmatrix} r_{11}^{(i)} & r_{12}^{(i)} & \cdots & r_{1n}^{(i)} \\ r_{21}^{(i)} & r_{22}^{(i)} & \cdots & r_{2n}^{(i)} \\ \cdots & \cdots & \cdots & \cdots \\ r_{c1}^{(i)} & r_{c2}^{(i)} & \cdots & r_{cn}^{(i)} \end{pmatrix}=(r_{hj})_{\propto n} \tag{21}$$

$$G_i=\begin{pmatrix} g_{11}^{(i)} & g_{12}^{(i)} & \cdots & g_{1n}^{(i)} \\ g_{21}^{(i)} & g_{2n}^{(i)} & \cdots & g_{2n}^{(i)} \\ \cdots & \cdots & \cdots & \cdots \\ g_{c1}^{(i)} & g_{c2}^{(i)} & \cdots & g_{cn}^{(i)} \end{pmatrix}=\begin{pmatrix} 1 & 1 & \cdots & 1 \\ 1 & 1 & \cdots & 1 \\ \cdots & \cdots & \cdots & \cdots \\ 1 & 1 & \cdots & 1 \end{pmatrix}=(g_{hj}^{(i)})_{c\times n} \tag{22}$$

G_i is the optimal decision fuzzy relationship matrix from the decision evaluation set V to the decision set D with respect to the objective i synthesized (h,j):

$$B_i=\begin{pmatrix} b_{11}^{(i)} & b_{12}^{(i)} & \cdots & b_{1n}^{(i)} \\ b_{21}^{(i)} & b_{2n}^{(i)} & \cdots & b_{2n}^{(i)} \\ \cdots & \cdots & \cdots & \cdots \\ b_{c1}^{(i)} & b_{c2}^{(i)} & \cdots & b_{cn}^{(i)} \end{pmatrix}=\begin{pmatrix} 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & 0 \end{pmatrix}=(b_{hj}^{(i)})_{c\times n} \tag{23}$$

B_i is the worst decision fuzzy relationship matrix from the evaluation set V to the decision set D with respect to the objective i synthesized (h,j). Eq. (16) becomes:

$$\min\left\{F(u_{hj})=u_{hj}^2\left[\sum_{i=1}^{k}\left(w_i(g_{hj}^{(i)}-r_{hj}^{(i)})\right)^p\right]^2\right.$$

$$\left.+(1-u_{hj})^2\left[\sum_{i=1}^{k}\left(w_i(r_{hj}^{(i)}-b_{hj}^{(i)})\right)^p\right]^2\right\} \tag{24}$$

Deriving the above equation and making the derivative zero gives:

$$u_{hj}=\frac{1}{1+\left\{\frac{\sum_{i=1}^{k}\left[w_i\left(g_{hj}^{(i)}-r_{hj}^{(i)}\right)\right]^2}{\sum_{i=1}^{k}\left[w_i\left(r_{hj}^{(i)}-b_{hj}^{(i)}\right)\right]^2}\right\}^2} \tag{25}$$

is obtained from matrices (21), (22):

$$u_{hj}=\frac{1}{1+\left\{\frac{\sum_{i=1}^{k}\left[w_i\left(1-r_{hj}^{(i)}\right)\right]^2}{\sum_{i=1}^{k}\left[w_i\left(r_{hj}^{(i)}\right)\right]^2}\right\}^2} \tag{26}$$

The above equation is called the fuzzy relationship preference model for fuzzy comprehensive evaluation of system level indicators.

3. Analysis of the Effect of Improving the Quality of Physical Education Teaching in Colleges and Universities

3.1. The Construction of the Evaluation Index System of School Physical Education Teaching Quality

3.1.1. Initial Selection of Indicators

Based on the fuzzy comprehensive assessment model of the hierarchical analysis method, and taking into account the overall and systematic characteristics of school physical education in Q city, the first-level evaluation indexes were established from the four levels of background, input, process, and result. The evaluation index system of school physical education quality is shown in Table 1.

Table 1. School sports teaching quality evaluation index system.

General purpose	Primary indicator	Secondary indicator
Evaluation of school sports teaching quality	A: Evaluation of school sports teaching background	A1: Culture target
		A2: Demand for all parties
		A3: School environment
	B: Evaluation of school sports teaching	B1: School sports teaching faculty
		B2: The hardware and software facilities of school sports teaching
		B3: School education
		B4: The school sports teaching group is guaranteed
	C: Evaluation of school sports teaching process	C1: Student performance
		C2: Teacher performance

		C3: The overall performance of the teaching activities
		C4: Physical education
	D: Evaluation of school sports teaching results	D1: Teacher harvest
		D2: Student gain
		D3: Teaching overall effect

3.1.2. Screening and Identification of Indicators

Expert questionnaires consisting of pre-selected primary and secondary indicators were sent out and returned to all experts, and the parameters of "importance" and "operationalization" were measured for each indicator in turn by SPSS standards and filtered according to the experts' opinions. Filtering. The results of the analysis of the importance of the indicators at all levels are shown in Table 2. The results show that: all the experts' level 1 and level 2 indexes have maintained great consistency and have been evaluated to reach a mean of ≥4 and a coefficient of variation of ≤0.18 at the same time, which indicates that all the experts tend to be consistent in the assessment of the importance and operability of level 1 and level 2 indexes, and concludes that through the screening of the level 1 indexes of all the experts: evaluation of the background of physical education teaching in schools, evaluation of the input of physical education teaching in schools, evaluation of the process of physical education teaching in schools, and evaluation of the operationalization of physical education teaching in schools. The conclusion is that through the screening of all the experts, the first-level indexes: evaluation of school physical education teaching background, evaluation of school physical education teaching process and evaluation of school physical education teaching results; and the second-level indexes: cultivation objectives, needs of all parties, school environment, teaching staff, hardware and software facilities, funding, organizational and institutional safeguards, performance of students, performance of teachers, performance of the overall performance of teaching and learning activities, elements of physical education curricula, gains of students, gains of teachers, and the overall effect of teaching and learning are more reasonable in terms of their importance and practicability.

Table 2. Analysis of indicators of indicators at all levels.

Primary indicator	Mean value	Standard deviation	Variation coefficient	Secondary indicator	Mean value	Standard deviation	Variation coefficient
A	4.06	0.6684	0.1675	A1	4.18	0.6348	0.1537
				A2	4.43	0.515	0.1183
				A3	4.91	0.4821	0.1011
B	4.51	0.5147	0.1185	B1	4.03	0.6655	0.1682
				B2	4.15	0.5727	0.1379
				B3	4.65	0.5287	0.1168
				B4	4.92	0.4229	0.088
C	4.98	0.4814	0.1041	C1	4.97	0.3133	0.0665
				C2	4.73	0.4833	0.1022
				C3	4.06	0.6673	0.1653
				C4	4.09	0.6651	0.1673
D	4.13	0.6684	0.1654	D1	4.76	0.4834	0.1022
				D2	4.84	0.4233	0.0884
				D3	4.29	0.4212	0.0968

3.1.3. Judgment Matrix Construction of Physical Education Teaching Quality Evaluation Indicators

On the basis of expert consultation and discussion, the evaluation matrix of the evaluation indicators of school physical education quality at each level and the previous level is proposed: using the relevant principles and procedures of AHP, the first-level indicators of school physical education teaching quality are compared two by two to form a matrix. The values of the judgment matrix of the first-level indicators are shown in Table 3, and the comparison matrix of the background evaluation, input evaluation, process evaluation and result evaluation of school physical education was established.

Table 3. The first level index determines the matrix value.

	A	B	C	D
A	1	1/5	1/7	1/3
B	5	1	1/2	1
C	7	2	1	2
D	3	1	1/2	1

The second-level indicators were compared and analyzed, and the second-level indicator comparison matrix of the school physical education teaching quality evaluation index system was established, and the values of the second-level indicator judgment matrix are shown in Table 4.

Table 4. The second level index determines the matrix value.

A: Evaluation of school sports teaching background		A1	A2	A3
	A1	1	1/3	1
	A2	3	1	2
	A3	1	1/2	1

B: Evaluation of school sports teaching		B1	B2	B3	B4
	B1	1	1/3	1/2	1/7
	B2	3	1	2	1/5
	B3	2	1/2	1	1/4
	B4	7	5	4	1
C: Evaluation of school sports teaching process		C1	C2	C3	C4
	C1	1	1/3	1/6	1/9
	C2	3	1	1/4	1/8
	C3	6	4	1	1/3
	C4	9	8	3	1

D: Evaluation of school sports teaching results		D1	D2	D3
	D1	1	1/5	1/3
	D2	5	1	2
	D3	3	1/2	1

3.1.4. Consistency test of judgment matrix and determination of weights

In each judgment matrix of the previous step, the largest eigenvalue is found separately and substituted into the consistency index CR for verification, and the consistency test results of each judgment matrix are shown in Table 5. From the table, it can be seen that the CR value of each index is below 0.08, that is, through the consistency test, the judgment matrix of each index is reasonable.

Table 5. Test results of matrix consistency.

Matrix	*λ*max	*CR*
Evaluation of school sports teaching quality	4.0269	0.0091
A: Evaluation of school sports teaching background	3.0145	0.0175
B: Evaluation of school sports teaching	4.0999	0.0365
C: Evaluation of school sports teaching process	4.1748	0.0659
D: Evaluation of school sports teaching results	3.0054	0.0038

The weight values of the indicators of the school physical education teaching quality evaluation system are shown in Table 6. As can be seen from the table, in the evaluation of the quality of school physical education teaching, the weight of the first indicator is as follows: evaluation of the process of school physical education teaching (0.4363) > evaluation of the input of school physical education teaching (0.3091) > evaluation of the results of school physical education teaching (0.1935) > evaluation of the background of school physical education teaching (0.0611). It can be seen that the evaluation of the process of teaching school physical education accounts for the largest weight, followed by the evaluation of the results of teaching school physical education and the evaluation of the input of teaching school physical education, and the evaluation of the background of teaching school physical education has a relatively weak influence. As can be seen from the comprehensive weighting, the overall performance of physical education curriculum elements and physical education teaching activities in the process evaluation, the organizational and institutional guarantee of school physical education teaching in the input evaluation, and the teachers' harvest index in the outcome evaluation have an important role in the evaluation of the quality of school physical education teaching, and therefore the improvement of these aspects should be focused on in the quality of school physical education teaching.

Table 6. The quality evaluation system of school sports teaching is the weight value.

General purpose	Primary indicator	Primary weight	Secondary indicator	Secondary weight	Secondary synthetic weight	Sort
Evaluation of school sports teaching quality	A	0.0611	A1	0.2016	0.0125	13
			A2	0.6003	0.0364	9
			A3	0.1981	0.0122	14
	B	0.3091	B1	0.081	0.0246	10
			B2	0.2304	0.0712	5
			B3	0.1505	0.0453	8
			B4	0.5381	0.168	2
	C	0.4363	C1	0.0508	0.0235	11
			C2	0.1583	0.0704	6
			C3	0.3177	0.1409	3
			C4	0.4732	0.2015	1
	D	0.1935	D1	0.1103	0.0203	12
			D2	0.5584	0.108	4
			D3	0.3313	0.0652	7

3.2. Practical use of student evaluation index system in physical education teaching

3.2.1. Practical application process

(1) Establishing the evaluation factor set

According to the index system of student evaluation of teaching quality in college physical education classroom constructed in this study, the evaluation factor set is determined, namely:

Tier 1 indicators: $\text{Primary indicator} = (A, B, C, D)$

Secondary indicators: $A = (A_1, A_2, A_3)$

……

$D = (D_1, D_2, D_3)$

Where A, B, C, D denote the four first-level indicators, and $A_{1-3}, B_{1-4}, C_{1-4}, D_{1-3}$ denote the second-level indicators under the first-level indicators.

(2) Establishment of hierarchical evaluation language set

According to the stepwise relationship of importance, the evaluation phrases of each level are set as $V = (V_1, V_2, V_3, V_4, V_5) =$ (excellent, good, fair, qualified, to be improved), and the corresponding scores for each level are $V = (5, 4, 3, 2, 1)$.

(3) Indicator weight set

According to the weight of each indicator obtained from the hierarchical analysis method to establish the indicator weight set:

Level 1 indicator: $W_{ABCD} = (0.0611, 0.3091, 0.4363, 0.1935)$

Secondary Indicator: $W_{A1-A3} = (0.0125, 0.0364, 0.0122)$

……

$W_{D1-D3} = (0.0203, 0.108, 0.0652)$

(4) Fuzzy comprehensive evaluation judgment matrix

According to the above research method and process of handling the frequency of the evaluation result rating scale, the fuzzy comprehensive evaluation judgment matrix is constructed in this study.

(5) Fuzzy comprehensive evaluation

Adopting the weighted average $M(*, +)$, according to the weight coefficients of each index already obtained above, the synthesis operation is carried out to obtain the first-level comprehensive evaluation score. The obtained first-level fuzzy comprehensive evaluation score is weighted with the hierarchical evaluation language set, and the first-level fuzzy evaluation of each indicator score is shown in Figure 1.

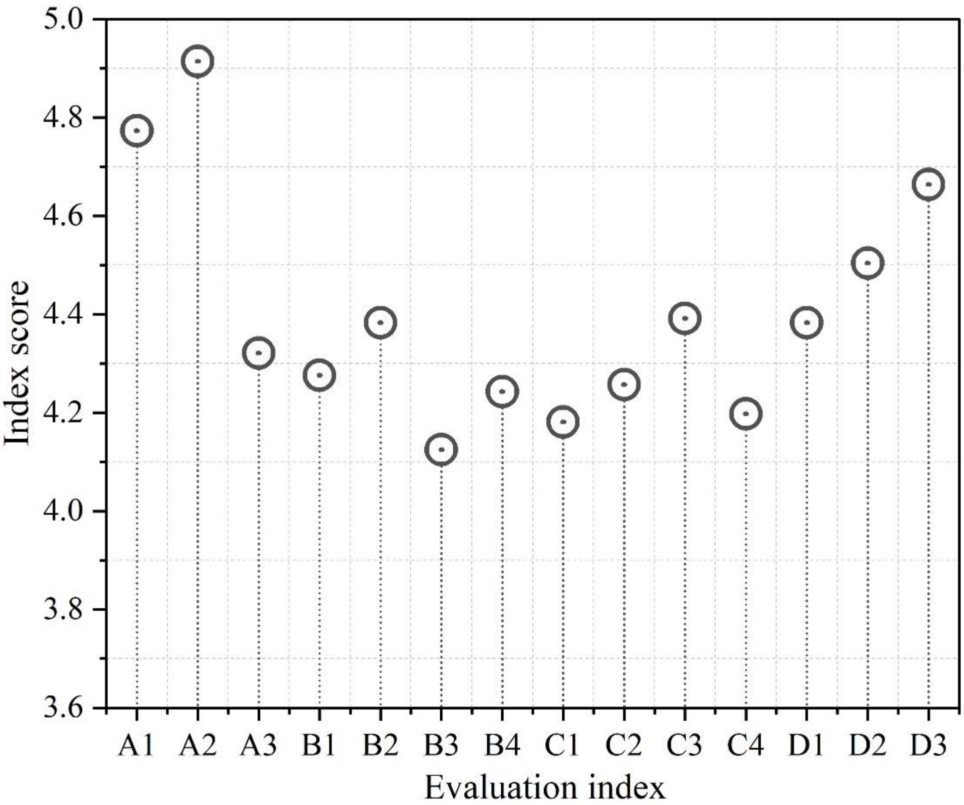

Figure 1. Level 1 fuzzy evaluation index score.

The second level fuzzy comprehensive evaluation is obtained from the first level fuzzy comprehensive evaluation row variables. The obtained second-level fuzzy comprehensive evaluation scores are weighted with the hierarchical evaluation language set to obtain the scores of each indicator. The second-level fuzzy evaluation scores for each indicator are shown in Table 7.

Table 7. The second level fuzzy evaluation indexes score.

Secondary fuzzy evaluation	A	B	C	D
Index score	3.9528	4.76895	4.96799	4.41635

3.2.2. Results and Analysis of Practice Application

The results of the above practical use of fuzzy comprehensive evaluation is a reflection of the quality of physical education classroom teaching in the selected classes, according to the evaluation results found that the quality of physical education classroom teaching in the university is good, but the purpose of the evaluation is not only to stay in the rating and quality of the determination of the quality of good and bad, the results of the evaluation to make an in-depth analysis, to find out the quality of the classroom teaching of the existing strengths and weaknesses, so as to make teaching improvements, and to promote the development of the quality of teaching.

In the fuzzy comprehensive evaluation of student assessment index system of physical education classroom teaching quality in colleges and universities constructed by this study, it can be seen that the scores of each index at each level are different. Through the scores of school sports teaching background, teaching input, teaching process and teaching results, it can be seen that the teaching process has the highest score close to excellent among the four first-level indicators, indicating that the teaching process of teachers is recognized by students and meets the needs of classroom teaching to a large extent. While the other indicators reach a good level, the teaching context scores below 4, which is only an average level, which also indicates that the evaluation of the teaching context should be further strengthened as a percentage. The scores of the indicators under each level of indicators were analyzed to further understand the advantages and disadvantages of classroom teaching activities.

The scores of the indicators under the teaching process are all around 4.96799, which is good, in which the teacher's demonstration and explanation of the adequacy of preparation, dress and behavior are recognized by most students, and most of them are given as excellent in the grade evaluation. Teaching input under the indicator scored around 4.76895, in which most of the students think that the teacher's teaching input is good, but further enhancement should be made. Compared with the rationality and diversity of teaching results, most students think that the rationality of teaching results is average, and they think that the difficulty and capacity of teaching results as well as meeting students' needs are still lacking, and more students chose good and average, and teachers should make improvements in this area to develop the quality of teaching. The overall teaching context is scored as 3.9528, with scores around 4.0 in its subordinate content, in which students' second-level composite weighting of the overall effectiveness of teaching is relatively high, but there is still room for improvement in terms of student gains.

3.3. Analysis of empirical results

3.3.1. Conditional variable necessity analysis

This paper analyzes the causal complexity of the effect of cultivating innovative talents in physical education by taking 30 local colleges and universities in China as samples, and using 14 conditions under the four dimensions of “teaching background, teaching evaluation, teaching process and teaching performance” as variables. After the final calibration of the case sample data, necessity analysis was conducted for each condition variable. Necessity analysis is a key step in quantifying the extent to which a single condition variable affects the outcome variable and provides the basis for fuzzy set truth table analysis. Firstly, necessity analysis of single variables is carried out, judged by consistency index, and 0.95 is set as the consistency threshold. Table 8 shows the results of necessity analysis of conditional variables. The results show that the maximum value of consistency of all conditional variables is 0.8741, which does not reach the standard of necessity, which indicates that single conditional variable is not a necessary condition for the outcome variable in this study, therefore, single conditional variable can't be the key element to enhance the effect of improving the quality of teaching and learning of physical education in local colleges and universities on its own.

Table 8. The necessity analysis of conditional variables.

Conditional variable	High innovation talent training effect		Low innovation talent training effect	
	Consistency	Coverage	Consistency	Coverage
A1	0.7559	0.8897	0.4822	0.4004
A2	0.502	0.5746	0.8744	0.71
A3	0.7848	0.8713	0.4899	0.3894
B1	0.4512	0.5549	0.8389	0.7311
B2	0.7912	0.864	0.5228	0.4085
B3	0.4552	0.571	0.8325	0.7391
B4	0.5417	0.6984	0.6367	0.5799
C1	0.6757	0.7206	0.6719	0.4989
C2	0.6174	0.6775	0.6368	0.5036
C3	0.5479	0.6783	0.5985	0.5205
C4	0.7741	0.8767	0.4773	0.3863
D1	0.4587	0.5517	0.8569	0.7284
D2	0.6824	0.8317	0.8741	0.7795
D3	0.8348	0.6973	0.8094	0.6015

3.3.2. Conditional configuration sufficiency analysis

This study focuses on 30 local sports colleges and universities in China, and provides insights into the multiple combinations of conditions that influence these colleges and universities to achieve quality improvement in physical education teaching. The study set four key condition variables and explored 36 different condition combination paths accordingly. In the specific analysis process, the case frequency threshold was set at 1, and the original consistency threshold as well as the PRI consistency threshold were both 0.95. Three kinds of solutions, namely, the parsimonious solution, the intermediate solution, and the complex solution, were obtained through the standard analysis process. The intermediate solution was preferentially selected as the main basis of group analysis, and the condition that only appeared in the intermediate solution was regarded as the marginal condition, while the condition that both the intermediate solution and the parsimonious solution existed was regarded as the core condition. The group states of the effect of improving the quality of physical education teaching in local colleges and universities are shown in Table 9, where ● indicates the presence of core conditions, • indicates the presence of marginal conditions, ⨂ indicates the absence of core conditions, ⊗ indicates the absence of marginal conditions, and blank indicates that the variable is irrelevant to the results.

There are a total of nine grouping patterns: where each column serves as a grouping solution, the total consistency reaches 0.9349, a value that indicates that nearly 93% of the university cases that conform to the nine conditional groupings analyzed demonstrate a high level of quality in terms of teaching quality improvement. Meanwhile, the total coverage reaches 0.7896, showing that these nine conditional groupings can effectively explain about 79% of the successful cases of teaching quality improvement, which fully verifies the importance and effectiveness of these conditional groupings in the process of talent cultivation.

Table 9. The university sports innovation talents cultivate the effect group state.

Conditional variable	Conditional configuration pattern								
	1	2	3	4	5	6	7	8	9
A	•	●	●	⊗	●	●	●	•	●
B	●	●	•	●	⊗	⊗	●	⨂	⊗
C	●	●		●	●	•	⊗	⨂	●
D	⨂	•	⊗		⨂	●	⨂	●	●
Consistency	0.9805	0.9797	0.9797	0.9786	0.9791	0.9798	0.9817	0.9774	0.9818
Original coverage	0.3003	0.3012	0.301	0.2998	0.3003	0.2991	0.2998	0.299	0.3009
Unique coverage	0.0401	0.0401	0.0404	0.04	0.0395	0.0401	0.0404	0.0394	0.0399
Total consistency	0.9349								
Total coverage	0.7896								

In order to comprehensively and systematically analyze the connotation of each configuration, the detailed results of the above nine configurations are explained one by one. In order to further clarify the specific realization of each configuration, each configuration is analyzed in depth and explained and analyzed in more detail as follows:

(1) Configuration 1: Dual-core Driven Talent Cultivation Model of Practical Teaching and Teaching Staff. Practical teaching and faculty as the core conditions in the process of talent cultivation occupies a dominant position.

(2) Grouping 2: three-core driven, teaching management deficient talent cultivation mode. Curriculum and teaching content, practical teaching links, and faculty together constitute the key framework for promoting the quality of physical education teaching.

(3) Configuration 3: Core curriculum-driven, practice-assisted talent cultivation model. Curriculum and teaching content and teaching management and assessment together constitute the core driving force to lead the cultivation of talents.

(4) Formation 4: Practice-oriented and teacher-dependent talent cultivation model. The practice teaching link and the faculty together constitute the core power of talent training. Practical teaching sessions provide students with the opportunity to apply theoretical knowledge in practice, and cultivate students' practical operation ability and problem solving ability.

(5) Configuration 5: Theoretical faculty double-driven, practice autonomous talent training mode.

This mode highlights the core position of curriculum and teaching content, faculty in talent cultivation, and emphasizes the fundamentals of theoretical knowledge and professionalism.

(6) Grouping 6: policy-led theoretical faculty dual-core talent training model. This mode takes curriculum and teaching content, faculty and policies and regulations as the core conditions, indicating that colleges and universities attach importance to the cultivation of theoretical knowledge and professional faculty in the process of talent cultivation, and at the same time emphasize the guiding role of policies and regulations.

(7) Grouping 7: Policy and Curriculum Driven Talent Cultivation Model. The model's curriculum and teaching content occupy a central position, while receiving strong support from policies and regulations.

(8) Formation 8: Balanced Development Talent Cultivation Mode. The conditions of curriculum and teaching content, practical teaching links, faculty, teaching management and evaluation, policies and regulations, and industry environment are all in a marginal position.

(9) Configuration 9: Core three-factor-driven talent cultivation mode. In this model, curriculum and teaching content, practical teaching links and faculty as the core conditions, together constitute the main driving force to promote the quality of personnel training.

4. Conclusion

This paper analyzes the influencing factors of teachers' physical education teaching quality, establishes a comprehensive evaluation index system of teachers' teaching quality, and combines the hierarchical analysis method and multi-objective fuzzy decision-making model for teaching quality improvement. The results show that:

(1) This paper determines the evaluation indexes of school physical education teaching quality from four aspects: background, input, teaching and results, and finally determines the evaluation index system with 4 first-level dimensions and 14 second-level dimensions. Through the hierarchical analysis method to assign weights to the indicators at all levels, it is found that among the four first-level dimensions, the weight of the evaluation of the process of school physical education teaching and the evaluation of inputs is higher, respectively 0.4363 and 0.3091, and the weight of the teaching background is the lowest, accounting for only 0.0611, which shows that the importance of the different indicators in physical education teaching is of different proportions.

(2) The overall teaching quality of college physical education classroom under the students' perspective is scored as good, in which the scores of each index are different, and it can be clearly seen that different indexes score advantages and disadvantages, which further verifies the measurability and applicability of the index system.

(3) The study analyzed 9 group paths of physical education teaching quality improvement in colleges and universities that are adapted to physical education teaching quality improvement, in which the coverage of group 9 is 0.7896, which means that the path can explain about 80% of the cases of physical education teaching quality improvement in colleges and universities. After the analysis of the group paths, it is found that the cutting-edge of curriculum, the strengthening of practical teaching, the optimization of the faculty, and the improvement of teaching management and evaluation are the key factors affecting the improvement of teaching quality, and colleges and universities should pay special attention to the construction and development of these aspects in the process of talent cultivation.

References

1. Li, J. (2021). Application of mobile information system based on internet in college physical education classroom teaching. Mobile Information Systems, 2021(1), 1481070.
2. Zhou, N. (2021, August). Research on the innovative development of college physical education teaching mode under the environment of computer technology and network. In Journal of Physics: Conference Series (Vol. 1992, No. 2, p. 022121). IOP Publishing.
3. Gu, Q. (2022). Research on the Reform and Innovation of Physical Education Management in Colleges and Universities under the New Situation. Open Journal of Social Sciences, 10(12), 459-465.
4. Jiang, W. (2024). Strategizing Physical Education Development in Higher Education: A Global Life Health and Biotechnological Approach. Journal of Commercial Biotechnology, 29(6), 275-283.
5. Wang, J., Wang, S., Qiao, Y., & Zhang, R. (2025). ExpTODIM-EDAS Framework for Multiple-Attribute Decision-Making under Z-number Environment and Applications to Physical Education Teaching Quality Evaluation. International Journal of Fuzzy Systems, 1-13.
6. Xiao, J., & Zhang, Y. (2025). Enhanced TOPSIS-CoCoSo framework for multi-attribute decision-making with triangular fuzzy neutrosophic sets:“effect evaluation of intelligent technology empowering physical education teaching” case. Soft Computing, 1-15.
7. Yuan, C., Yang, Y., & Liu, Y. (2021). Sports decision-making model based on data mining and neural network. Neural Computing and Applications, 33, 3911-3924.

8. Hu, W., & Liu, Y. (2024). Evaluation Model of the Teaching Effect of College Physical Education Class Based on Multimedia Feature Extraction Technology and Three-Dimensional Recons. International Journal of e-Collaboration (IJeC), 20(1), 1-20.
9. Zong, X., Lipowski, M., Liu, T., Qiao, M., & Bo, Q. (2022). The sustainable development of psychological education in students' learning concept in physical education based on machine learning and the internet of things. Sustainability, 14(23), 15947.
10. Zheng, W., Ma, Y. Y., & Lin, H. L. (2021). Research on blended learning in physical education during the COVID-19 pandemic: A case study of Chinese students. Sage Open, 11(4), 21582440211058196.
11. Raiola, G., & Tafuri, D. (2015). Teaching method of physical education and sports by prescriptive or heuristic learning. Journal of Human Sport and Exercise, 10(1), S377-S384.
12. Casey, A., & MacPhail, A. (2018). Adopting a models-based approach to teaching physical education. Physical Education and Sport Pedagogy, 23(3), 294-310.
13. Liu, F. (2021, February). Era of big data is based on the study of physical education teaching mode in MOOC. In Journal of Physics: Conference Series (Vol. 1744, No. 3, p. 032008). IOP Publishing.
14. Yu, Y., & Yan, B. (2016). Research on promotion of teaching quality with a new physical education teaching mode based on virtual reality. Revista Ibérica De Sistemas e Tecnologias De Informação, (E9), 46.
15. Chen Lili,Baza Mohamed & Alshahrani Hani. (2023). Data Integration Method of Multi-source Feedback Evaluation for Remote Teaching Quality. Mobile Networks and Applications,28(3),924-934.
16. Jie Zhang,Shuxia Wang,Weiping He,Jianghong Li,Shixin Wu,Zhiwei Cao & Manxian Wang. (2024). Perception and Decision-Making for Multi-Modal Interaction Based on Fuzzy Theory in the Dynamic Environment. International Journal of Human–Computer Interaction,40(24),8794-8808.