Intelligent Computing Technology and Automation
Z. Hou (Ed.)

doi:10.3233/ATDE231255

A Comprehensive Evaluation Method for Physical Education Teaching Quality Based on Fuzzy Clustering

Bin GU[a,1], Bangming WEI[a]
[a] *Chengdu Neusoft University Basic Teaching College, Chegndu, 611844, China*

Abstract. Physical education curriculum evaluation is an important aspect of physical education teaching, and there are multiple uncertain factors in the evaluation process. This article proposes a comprehensive evaluation method for physical education teaching quality based on fuzzy clustering, contraposing to the characteristic that traditional fuzzy comprehensive evaluation cannot reflect the dynamic changes in physical education teaching quality. Our plan comprehensively considers the impact of teaching system and student learning system on the quality of physical education teaching, and establishes a comprehensive evaluation index system. Then, the teaching situation of the evaluated teachers is appropriately classified, and a fuzzy dynamic clustering model for evaluating teacher teaching quality is also constructed. The final weight of factors acquired through fuzzy classification is used to determine the ranking structure of teachers' teaching quality. The case analysis shows that the clustering analysis method in this article can clearly reflect the significant differences in the teaching quality of teachers, effectively realizing the diagnostic function of physical education teaching evaluation, and providing a basis for information feedback with different teaching characteristics.

Keyword: fuzzy classification; comprehensive evaluation; teaching quality; physical education; clustering

1. Introduction

A scientific teaching evaluation system should strictly judge the value of the teaching process and results based on teaching objectives, and serve teaching decision-making. With the emergence of new ideas and models in physical education teaching, the original teaching quality evaluation system can no longer fully meet the requirements of the current development of physical education curriculum in universities. The reason for this is that the assessment of teaching quality is a relatively subjective problem, and it is difficult to achieve objectivity and accuracy in practical operation. In addition, the lack of completeness of assessment factors makes the credibility of evaluation results even worse. Due to the numerous factors and complex relationships that affect the quality of physical education teaching, as well as the widespread non quantitative phenomenon of evaluation factors, the fuzzy and comprehensive characteristics of classroom teaching quality evaluation are determined [1].

Fuzzy decision-making is a scientific decision-making process that uses fuzzy mathematics as a tool and applies fuzzy theory and methods to deal with a large number of fuzzy phenomena and problems in reality. Fuzzy decision-making is a

[1] Corresponding Author: Bin GU; Chengdu Neusoft University Basic Teaching College, Chegndu, 611844, China; bingu999@126.com

product of the combination of fuzzy technology and decision-making methods, consisting of three parts: fuzzification, fuzzy reasoning, and fuzzification. Fuzzification is the process of converting precise inputs into a fuzzy input set, achieved through membership functions; Fuzzy thrust refers to the mapping from fuzzy input set to fuzzy output set through certain calculations. The commonly used methods include fuzzy rule reasoning, fuzzy comprehensive evaluation, fuzzy statistical judgment, etc. Defuzzification is the process of converting a fuzzy output set into an accurate output set. The commonly used strategies include the maximum membership principle, fuzzy centroid method, Gaussian transform distribution method, etc. [2-4]

This article analyzes and studies the teaching quality of physical education teachers through cluster analysis and TOPSIS, and finds that it includes multiple aspects such as teachers' level of knowledge, educational concepts, and teaching research abilities. We first use factor analysis to determine common teaching quality evaluation indicators, so that the algorithm has a scientific basis. Then, the standardized data is generated into an approximation matrix through fuzzy clustering, and compared one by one to obtain more objective weight values. Finally, a comprehensive examination of the evaluation method in this article was conducted through the actual performance and case analysis of a certain university's sports academic affairs. The experimental results show that using fuzzy set theory to conduct fuzzy comprehensive evaluation of the teaching quality of physical education teachers can obtain accurate clustering and evaluation results, thereby promoting teachers to improve their own weak indicators in a targeted manner, and also helping students learn more professional knowledge from the entire classroom teaching.

2. Teaching Quality Index System

The evaluation system of physical education teaching refers to a system composed of multiple organically connected teaching elements in the evaluation of physical education teaching, which correctly evaluates and evaluates teaching activities and their impacts based on standards, understands feedback on teaching activities, and can improve and optimize them in a timely manner. For the evaluation index system of physical education teaching, in addition to considering traditional teaching quality indicators, the following modern teaching characteristics can also be emphasized:

Academic: Evaluate whether physical education teaching emphasizes the impartation of theoretical knowledge and the cultivation of disciplinary connotations, including knowledge in sports science, sports physiology, sports psychology, and other fields.

Ideological: Evaluate whether physical education teaching focuses on cultivating students' thinking ability and innovative consciousness, encouraging students to analyze, solve problems, and think critically.

Artistic: Evaluate whether physical education teaching emphasizes the cultivation of students' artistic expression ability and aesthetic awareness, including the cultivation of graceful movements and coordinated body shape

Interactivity: Evaluate whether physical education teaching emphasizes interaction between teachers and students, as well as cooperation between students. Encourage students to participate in discussions, share experiences, and collaborate in practice, and promote the cultivation of students' communication and cooperation abilities.

These evaluation indicators of modern teaching characteristics can help teachers

comprehensively evaluate the quality of physical education teaching and promote the comprehensive development of students in academic, ideological, artistic, and interactive aspects. At the same time, this also helps to integrate physical education teaching with other disciplines and improve the comprehensive effectiveness of teaching.

This article formulates four primary indicators based on the teacher's teaching system and the student's learning system, and abstracts the common requirements of these indicators as 10 secondary indicators. Based on this, the quality of physical education curriculum teaching is evaluated. Based on the commonly used 1-9 scales in Analytic Hierarchy Process, we establish a paired comparison matrix, and then solve for the eigenvalues and eigenvectors of each comparison matrix. The obtained eigenvectors are the importance ranking of each evaluation element, which is weight allocation [5]. To verify whether the weight allocation is reasonable, we conduct consistency checks on each comparison matrix, and based on the test results, the final weight vector is determined as shown in Table 1.

Table 1. List of evaluation indicators for the quality of physical education teaching

1st level index	Weight	2nd level index	Weight	Evaluation level				
				excellent	good	average	fair	poor
Academic	0.4558	The scientificity and richness of the content	0.2236	40	18	11	30	1
		Syllabus level	0.1218	33	34	12	20	1
		Having cutting-edge characteristics	0.6546	43	25	8	23	1
		Promoting student inspiration	0.1529	30	27	10	23	9
Ideological	0.2793	Attract students' attention	0.3352	52	10	1	29	8
		Emphasize students' expression ability	0.5119	29	34	20	58	4
Artistic	0.2131	The cultivation of innovative and aesthetic consciousness	0.5614	33	32	21	13	5
		Exerting the Function of Teaching Emotions	0.4386	28	30	19	22	1
Interactivity	0.0518	Identify key points, difficulties, and cut into the topic	0.4812	34	21	14	30	1
		Improving students' practical abilities	0.5188	42	21	15	21	

3. Mathematical Model for Fuzzy Cluster Analysis

3.*1 Data Standardization*

Cluster analysis is a method of classifying things based on their different characteristics, degree of familiarity, and similarity. Using fuzzy mathematics to classify is called fuzzy clustering [6].

Assuming the domain $U = \{x_1, x_2, ..., x_n\}$ is the object to be classified and each object has m performance index, that is $x_i = \{x_1, x_2, ..., x_{im}\}$, $i = 1, 2, ..., n$,

then the original data matrix is $X = (x_{ij})_{n\times m}$.

To compare different data in the actual problems with different dimensions, the data are performed two kinds of transformation usually to compress the data in the range $[0,1]$.

(1) Translation and standard deviation transformation

$$x_{ik}^{'} = \frac{x_{ik} - \overline{x}_k}{s_k} \tag{1}$$

where $\overline{x}_k = \frac{1}{n}\sum_{i=1}^{n} x_{ik}$, $s_k = \frac{1}{n}\sum_{i=1}^{n} (x_{ik} - \overline{x}_k)^2$;

(2) Translation range transformation

$$x_{ik}^{''} = \frac{x_{ik}^{'} - \min\limits_{1\le i\le n}\{x_{ik}^{'}\}}{\max\limits_{1\le i\le n}\{x_{ik}^{'}\} - \min\limits_{1\le i\le n}\{x_{ik}^{'}\}}, \quad i = 1,2,...,n, \quad k = 1,2,...,m \tag{2}$$

3.2 Establishing Fuzzy Similarity Matrix

According to the similarity of x_i and x_j the fuzzy similarity matrix $R = (r_{ij})_{n\times n}$ is established and the computation of similarity coefficient includes the following methods:

(1) Quantity product method:

$$r_{ij} = \begin{cases} 1, & when\ i = j \\ \frac{1}{M}\sum_{k=1}^{m} x_{ik}\cdot x_{jk} & when\ i \neq j \end{cases} \tag{3}$$

(2) Angle cosine method:

$$r_{ij} = \frac{\sum_{k=1}^{m} x_{ik}\cdot x_{jk}}{\sum_{k=1}^{m} x_{ik}^2 \sum_{k=1}^{m} x_{jk}^2} \tag{4}$$

(3) Subjective scoring method

Compute the similarity matrix R by $R = (r_{ij})_{n\times m}$, $(1 \le i, j \le n)$

3.3 Clustering

If R is fuzzy equivalency relation, the elements in U can be classified in any level λ. The classification rule is: under level λ, x_i and x_j is similar $\Leftrightarrow r_{ij}^{(\lambda)}$ =1. When λ descends from 1 to 0 we can acquire a dynamic clustering graph. Then a suitable confidence level is needed to get form the graph to obtain needed classification; If R is not fuzzy equivalency relation it can be used to finish the classification. $t(R)$ can be adopted to classify the elements in U.

Under suitable λ^*, the n teachers to be evaluated are classified to several classed and the teaching quality in the same class are considered equivalent. To further evaluate the teacher rank, TOPSIS can be adopted for each teacher ranked in descending order of relative closeness, and the teacher ranked first has the best teaching quality in this category [7-9].

4. Empirical Analysis

Taking the evaluation of the teaching quality of 2022 grade physical education practical courses in a certain university as an example, the specific application of fuzzy comprehensive evaluation method is explained. By statistically analyzing the survey results of students, a fuzzy similarity matrix shown in Table 2 is established. In this example, the cosine calculation method of included angle is used to calculate the similarity coefficient.

Table 2. Proximity matrix of samples

Case	Cosine of vectors of values									
	1	2	3	4	5	6	7	8	9	10
1	1.000	.995	.996	.994	.998	.990	.982	.983	.989	.981
2	.995	1.000	.998	.987	.990	.994	.991	.991	.983	.994
3	.996	.998	1.000	.985.	.987	.987	.993	.995	..989	.993
4	.994	.987	.985	1.000	.992	.999	.995	.986	.985	.982
5	.998	.990	.987	.992	1.000	.989	.990	.989	.986	.990
6	.990	.994	.987	.999	.989	1.000	.984	.989	.992	.981
7	.982	.991	.993	.995	.990	.984	1.000	.981	.983	.989
8	.983	.991	.991	.995	.986	.989	.981	1.000	.994	.994
9	.989	.983	.989	.985	.986	.992	.983	.994	1.000	.994
10	.981	.994	.993	.982	.990	.981	.989	.994	.994	1.000

According to the scores of common factors F1, F2, and F3, the deviation square method is used for systematic Q-type clustering analysis Divide 14 sample teachers into 4 categories and select an appropriate distance measurement matrix (set as square distance in this article). Then, by calculating the distance matrix between samples, an initial clustering result can be obtained. According to the principle of cluster analysis, the data is processed using cluster analysis system software to obtain the initial distance matrix.

According to clustering algorithm integrate two classes G1 and G2 to one class G12. Based on Ward's method the new distance matrix is acquired. Then the two classes which has the nearest distance are combined to one class until these classes are combined to one class. Repeat above process and the clustering graph of the overall system is depicted as Figure 1.

From such clustering analysis graph all the sample teachers are divided to four classes: C1={T1, T7, T6, T10}, C2={T5, T8, T9}, C3={T3, T4, T11, T12}, C4={T2, T13,T14}.If we determine the actual feedback results of the teaching quality in our school, T1 class teachers are the best teachers in the school. Their teaching methods, attitudes, and effectiveness are unanimously recognized by students and peers, which is often seen as a positive indicator. This means that teachers or teaching teams demonstrate high-quality teaching methods, positive teaching attitudes, and can achieve good teaching outcomes during the teaching process. If the teaching quality of the surveyed teachers basically follows a normal distribution, it means that in terms of

teaching quality, most teachers' performance is concentrated near the average level, while the number of extremely excellent or extremely insufficient teachers is relatively small. Scientific guidance can be provided to teachers based on the results of classification, enabling them to make up for their shortcomings.

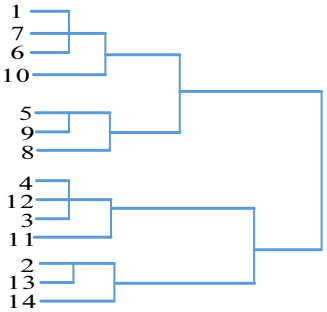

Figure 1. Clustering analysis graph.

Even under the same classification, there may be differences in teaching quality among individual teachers. Factors such as teachers' teaching style, teaching experience, and professional knowledge level may all affect the evaluation results of teaching quality. Therefore, when analyzing the teaching quality of teachers with different professional titles, it is necessary to consider the existence of individual differences [10-12]. Conduct corresponding teaching quality evaluations for teachers with different professional titles, and obtain the proportion of different levels in different professional titles, as shown in Figure 2.

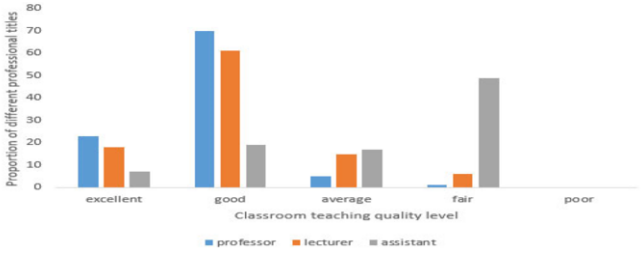

Figure 2. The proportion of different titles in different classes for quality evaluation.

From the results, it can be seen that professors have a higher proportion of excellent and good grades than lecturers and teaching assistants. This is because they usually have higher academic qualifications and rich teaching experience, and may be able to better utilize their professional knowledge and experience in the teaching process to provide higher quality teaching. The specific situation may vary depending on individual differences in teachers, evaluation standards, and evaluation methods. When conducting teacher evaluation, multiple factors should be comprehensively considered, including the teacher's teaching ability, teaching methods, student evaluation, to draw accurate and comprehensive conclusions.

The experiments show that the clustering analysis method proposed in this article can be used to classify teachers into different categories in teacher evaluation, in order to better understand and compare the characteristics and performance of different categories of teachers. Through cluster analysis, the percentage of teachers in different categories can be obtained to understand the proportion of each category of teacher in

the overall teacher group.

5. Conclusion and Future Work

This article uses fuzzy clustering method to classify and analyze the teaching of physical education teachers. By establishing a new indicator system for physical education teachers, the selected features are standardized to ensure that they have similar scales and ranges. This can prevent certain features from having a significant impact on the clustering results. In the actual operation process, by selecting appropriate similarity coefficients and establishing a fuzzy similarity matrix, direct clustering method is used for classification. By constructing a similarity matrix of teaching quality indicators, teachers can be divided into different categories based on their evaluation indicators, such as teaching ability, student interaction, course design, etc. In this way, the comprehensive performance of teachers can be evaluated more comprehensively, and targeted feedback and improvement suggestions can be provided to teachers. The actual case study results indicate that the teacher evaluation model constructed in this article is reasonable and feasible, and it can comprehensively evaluate at multiple levels and factors. The results of cluster analysis can provide insights into the teacher population and help identify subgroups of teachers with similar characteristics or performance. This helps education managers and decision-makers better understand the characteristics and needs of teachers, thus formulating corresponding strategies for teacher training, development, and support.

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