

# Research on the Application of Fuzzy Comprehensive Evaluation in the Teaching Performance Appraisal of College Teachers

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**Keywords:** College Teachers, Teaching Performance, Fuzzy Comprehensive Evaluation, Indicator System, Improvement and Perfection.

**Abstract:** As the dominant power of teaching activities, college teachers play an important role in the cultivation system of higher education. In order to judge the realistic value and potential value of their teaching activities, it is necessary to evaluate their teaching performance. For explicit content in teaching activities, quantitative methods can be used to carry out objective assessment; for the work content of implicit aspects, the objective assessment cannot be carried out directly due to the corresponding fuzzy concept. Therefore, a comprehensive evaluation method based on fuzzy mathematics is proposed. The indicator system including explicit and implicit contents is established according to the teaching activities of college teachers; the typical and authoritative assessment subject is determined; the fuzzy operator and weight value are reasonably determined through analysis and comparison. The final membership is calculated by using the above determining factors, and the assessment results of each evaluation object are obtained. In addition, the corresponding perfect and improved measures are put forward in accordance with the information feedback of the assessment results to achieve the purpose of stimulating teachers' teaching initiative to improve their performance, so as to provide methods for the implementation of relevant evaluation activities.

## 1 INTRODUCTION

College teachers serve as a decisive part in the smooth implementation of teaching activities. ZHAO (2011) Apart from the required teaching workload, they also undertake the formulation of training programs, curriculum construction, students' innovative practice guiding and other tasks (ZHAO, 2011). In order to evaluate the teaching performance of teachers while realizing their personal value, and to reflect the situation that teaching activities or phenomena satisfy certain explicit or implicit requirements, colleges and universities carry out regular assessments of their teaching performance. GEN (2009) The so-called "teaching performance evaluation" means that the university extensively collect the teaching activity information of individual teachers relying on modern technical means based on the formulated procedures and methods, and assess the value and fact of whether the process and results conform to the teaching objectives (GEN, 2009). Nevertheless, the explicit and implicit indicators involved in the evaluation

process will affect the objectivity of the assessment results. In this regard, the fuzzy comprehensive evaluation method is adopted in teaching performance assessment to make full use of teaching management, teaching transformation and teachers' professional progress in accordance with the evaluation results.

## 2 CURRENT SITUATION OF TEACHING PERFORMANCE EVALUATION

In order to make the teaching performance evaluated objectively, scholars at home and abroad have studied the evaluation methods from various viewpoint. CHEN (2017) The representative foreign evaluation methods include: value-added assessment, peer assessment, customized teaching and so on, yet some problems appear in these methods, such as long cycle and strong subjectivity (CHEN, 2017).

Considering the differences of evaluation objects and the operation difficulty in evaluation method, Chinese scholar DUAN (2013) proposed the teaching performance assessment method based on "BP neural network", and verified the feasibility of this method in assessment practice (DUAN, DENG, SHEN, 2013). Given the assessment subject of this study is mainly students, the final assessment results are certain restricted, so the scope of the assessment subject should be extended to supervision experts, teaching managers, employment units, etc. MA (2019) built the teaching performance evaluation indicator system from the aspects of teaching attitude and teaching content, and adopted the entropy weight TOPSIS model to realize the quantitative assessment of teaching performance (MA, 2019); LIU (2014) put forward the performance assessment method on the basis of the extension theory to address the subjective randomness in the process of qualitative assessment (LIU, ZHANG, 2014). However, the relevant assessment factors are limited to teaching and research papers, teaching workload and other explicit content, while ignoring the improvement of students' innovation capability and other implicit content; In view of the inadequate scientifically in teaching performance evaluation system and method that causes the deviation of evaluation results from actual situation, and then impairs the enthusiasm of teachers, SUN (2015) came up with an approach of teaching performance evaluation with "support vector machine method" (SUN, 2015). However, when constructing the teaching performance indicator system, the explicit and implicit requirements should be considered in an all-around way.

Moreover, the indicator factors have corresponding fuzzy concepts in the teaching performance evaluation of college teachers. To this end, Liu (2013) proposed the application of fuzzy theory in the teaching performance evaluation method, and constructed the corresponding assessment indicator system (Liu, Zhu, 2013), but the determination process of weight value is short of a reasonable basis; Zhao (2013) applied the hierarchy analysis method to establish the teaching performance evaluation matrix (Zhao, 2013), yet the determination of the fuzzy operator lacks rationality, which weakens the objectivity of the final assessment results; GAO (2020) put forward the "principal component analysis method" to evaluate

the teaching performance of teachers, and reasonably determine the weight value of assessment indicators, so that ensure the objectivity of the assessment results to the largest extent (GAO, LI, SONG, 2020). Given the massive data calculation and relatively single evaluation subject, the above methods have poor practicality.

On the basis of the previous researches, this study establishes a comprehensive evaluation indicator system to reasonably determine the fuzzy operators and weight values for the objective assessment of their teaching performance.

### 3 OVERVIEW OF FUZZY COMPREHENSIVE EVALUATION

The Fuzzy Theory was proposed by American scholars in the 1960s, and the fuzzy comprehensive evaluation method is an approach of comprehensive assessment based on the Fuzzy Theory. With this method, the qualitative evaluation can be transformed into quantitative evaluation, which is suitable for solving various non-deterministic problems, and for making an objective and comprehensive evaluation under different factors. Kember (2006) Since the teaching activities of college teachers involve a variety of factors with both implicit and explicit characteristics, some activities or phenomena even contain certain ambiguity (Kember, 2006). In this regard, the evaluation factor set is determined in the teaching performance evaluation through the analysis of the evaluation object; The hierarchy analysis method is applied to assign the weight of each factor involved in teaching activities, which decompose complex problems into several constituent components, a hierarchical structure is formed according to their dominating and dominated relation, and the relative importance of each component is identified in the hierarchy in comparison; Smith(2014)The investigation and study are conducted to determine the merits of the factors, so as to obtain the evaluation value of these factors (Smith, Vinson, Smith etc., 2014), and calculate the final membership degree based on the above process, as shown in Fig.1.

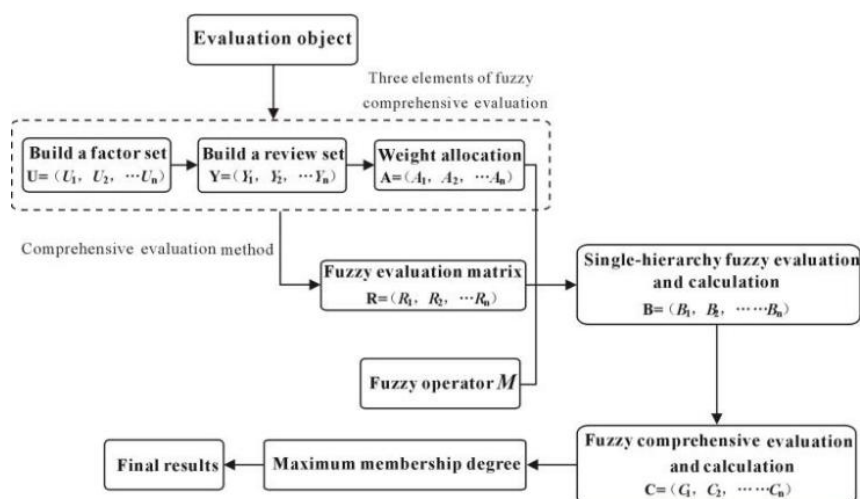


Figure 1 Fuzzy comprehensive evaluation flow chart

(1) Factor set: the indicator of fuzzy comprehensive evaluation, that is, the evaluation aspects;

(2) Review set: the quality degree of each evaluation factor, and the result collection of evaluation grades;

(3) Weight set: the weight value is to measure the importance of an indicator in the whole assessment indicator system, and the weight set is a set composed of each weight value (Butt Babar, Rehman, 2010). In order to make the fuzzy calculation process more logical and the assessment results more objective, the weight value of each indicator is determined by the authoritative professors in universities according to their expertise and experience: based on the estimation of experts, the final weight value of each indicator is calculated according to the method in Table 1, and the sum of each weight value should be 1, as shown in Equation (1).

Table 1 Weight calculation method of expert estimation

Factors index	$u_1$	$u_2$	...	$u_n$	$\Sigma$
Weight					
Experts					
Expert 1	$a_{11}$	$a_{12}$	...	$a_{1n}$	1
Expert 2	$a_{21}$	$a_{22}$	...	$a_{2n}$	1
...	...	...	...	...	1
Expert m	$a_{m1}$	$a_{m2}$	...	$a_{mn}$	1
$\frac{1}{m} \sum_j a_{ij}$	$\frac{1}{m} a_{11}$	$\frac{1}{m} a_{12}$	...	$\frac{1}{m} a_{1n}$	1

$$(a \geq 0; i=1, 2, \dots, n) \tag{1}$$

(4) Fuzzy relation matrix: the quantitative processing of qualitative indicators in the teaching performance of university teachers can be completed by fuzzy statistics method. the membership degree of evaluation grade is obtained after the assessment subject evaluates the qualitative indicator according to the grade domain, while the membership degree of each subsystem constitutes the membership set, and the fuzzy relation matrix of the assessment indicator is established. The corresponding mathematical representation is as shown in Equation (2):

$$R_{n \times m} = \begin{bmatrix} R_1 \\ R_2 \\ \dots \\ R_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{bmatrix} = (r_{ij})_{n \times m} \tag{2}$$

Where,  $(r_{11}, r_{12}, \dots, r_{im})$ : the evaluation set of individual indicator  $u_i$  ( $i=1, \dots, n$ );

$R_{n \times m}$ : refer to the evaluation set of all individual indicators.

(5) Single-hierarchy fuzzy evaluation calculation: the evaluation indicator is divided into several subsystems according to its characteristics. LI (2015) The single-hierarchy fuzzy evaluation is calculated based on the weight set and the fuzzy relation matrix in each system (LI, CHEN, 2015). The corresponding mathematical representation is as shown in Equation (3):

$$B = A \bullet R_{n \times m} = A \bullet \begin{bmatrix} R_1 \\ R_2 \\ \dots \\ R_n \end{bmatrix} = A \bullet \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{bmatrix} = A \bullet (r_{ij})_{n \times m} \tag{3}$$

Where, "A" is the weight set of evaluation indicators at all hierarchies;

"B" means a single-hierarchy evaluation set: it is calculated by the weight allocation and evaluation matrix of each factor.

(6) Fuzzy comprehensive evaluation calculation: the single-hierarchy fuzzy evaluation calculation results are taken as the relative membership degree matrix of the previous hierarchy, and the single-hierarchy fuzzy calculation model is used again to obtain the membership order of the assessment object. The corresponding mathematical representation is as shown in Equation (4):

$$C = A \bullet B = A \bullet \begin{bmatrix} B_1 \\ B_2 \\ \dots \\ B_n \end{bmatrix} = A \bullet \begin{bmatrix} A_1 \bullet R_1 \\ A_2 \bullet R_2 \\ \dots \bullet \dots \\ A_n \bullet R_n \end{bmatrix} = A \bullet (b_{ij})_{n \times m} \quad (4)$$

Where, "C" represents the final membership degree of the assessment indicator: that is, the weight allocation A of the primary indicator is calculated from the membership matrix composed of the single-hierarchy fuzzy evaluation calculation results of Equation (3).

## 4 THE APPLICATION OF FUZZY COMPREHENSIVE EVALUATION IN TEACHING PERFORMANCE ASSESSMENT

Most colleges and universities usually adopt the approaches of students evaluation, supervision team in lectures, teaching outcomes submission and so on in evaluation, the focus is only put on classroom organization, teaching methods, language expression, research papers, competition awards, etc., while ignoring the assessment of teaching effect, such as: Kenneth (2018) the increase of students' knowledge, enlightenment, innovation capability, and even problem discovery and solving ability in work (Kenneth, 2018). In addition, the growth of students is a gradual and long-term process, which makes it difficult to generate immediate effect in teaching activities, and the delay of such talent training has become a challenge in teaching performance assessment. Hence, in order to realize objective teaching performance assessment results, the evaluation indicator should be comprehensive, alongside with authoritative assessment subject as well as reasonable weight value and fuzzy operator, as shown in Fig. 2.

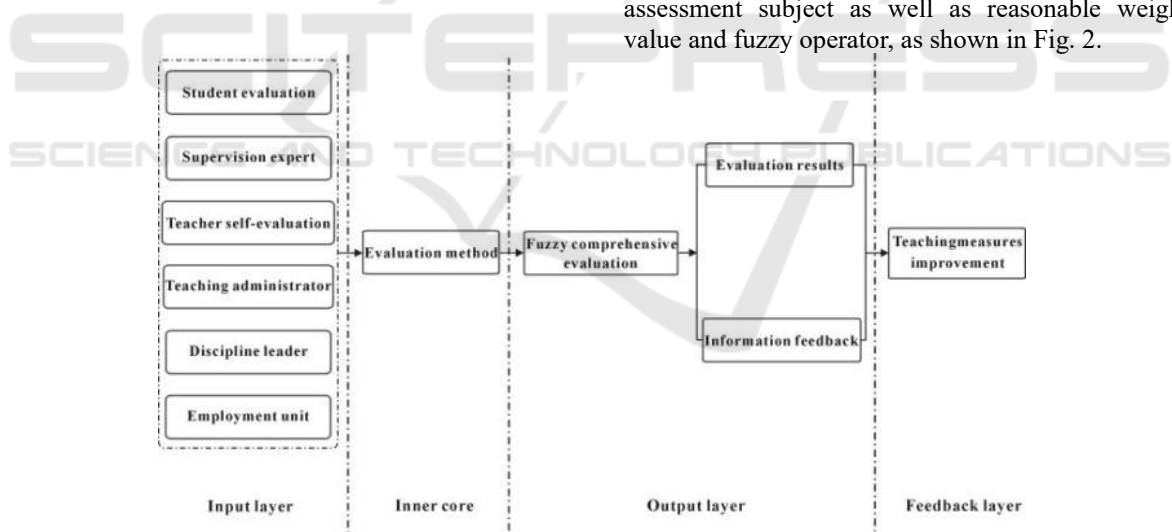


Figure 2. Teaching performance evaluation process

### 4.1 Selection of Teaching Performance Evaluation Subjects

The university teaching performance evaluation includes both explicit and recessive content, involving massive indicators interrelated to evaluation object. Thus, the objective and comprehensive performance evaluation requires diversified evaluation subjects consisting of

students, teachers, supervision experts, leaders, teaching administrators, and employment units to participate in the "multidimensional evaluation" system, so as to address the limitations bought by single subject evaluation.

Based on the teaching quality requirements of higher education, the university and secondary colleges randomly inspect and evaluate the classroom teaching activities of the teachers

according to the teaching quality requirements of higher education, mainly including: teaching preparation, teaching methods, language expression and other aspects. Due to the differences in professional knowledge, the evaluation pays more attention to the real-time situation, which is unable to fully recognize the role of the evaluated course in the curriculum system, thus making the evaluation limited to superficial teaching, while lack of profound content of the major and discipline, and difficult to truly reflect the knowledge absorption and emotion input of the evaluation object; Smith(2013)As the object of teaching and the direct reflection of the teaching effect, students play a crucial role in the process of teaching performance evaluation, who are also regarded as an important information source in the performance evaluation in terms of teaching attitude, teaching content and teaching effect (Smith, Jones, Gilbert etc., 2013): Influenced by subjective factors, students may miss the qualitative description and suggestion of teacher teaching effect; The teaching performance evaluation made by teaching administrators puts more emphasis on the "final results", and the formulation stress more indicators of completed teaching outcomes, such as teaching hours, guiding published papers, competition awards, yet short of the attention to teaching activities; The ultimate goal of teaching is to cultivate comprehensive and quality talents, evaluating the students' actual problem solving and innovation ability can indirectly reflect the teaching effect; Teacher self-evaluation refers to the personal assessment of overall teaching activities, mainly including: teaching process, discipline construction, innovative practice training. College teachers, as a group with strong cognitive competence, certainly have the ability of self-assessment and reflection. Hence, teachers' self-evaluation can fully reflect the actual performance; Discipline leader, serving as the direct head of teachers, are familiar with the situation of teachers' professional competence, discipline construction, curriculum construction and team cooperation, which is conducive to the direct feedback of teachers' teaching performance in multiple aspects.

#### **4.2 Construction of Teaching Performance Indicators**

In order to make the teaching performance evaluation of college teachers play a guiding and all-sided role, it is necessary to construct a scientific teaching performance evaluation indicator system.

The teaching performance evaluation of university teachers consists of final evaluation and formative evaluation, that is, the outcomes led by the teaching process and the teaching results.

Through the analysis on the teaching performance evaluation documents of different universities, questionnaire, survey and interview methods are adopted to study the relevant indicators and factors in teachers' teaching performance evaluation process. The assessment documents and interviews are mainly from Qilu University of Technology (Shandong Academy of Sciences), Shandong Normal University, Shandong University of Traditional Chinese Medicine and other universities, with a total of 32 interviewees including administrators and teachers of different professional titles; Among the 256 received questionnaires in 280 distributions, 248 are valid ones. According to investigation, the teaching performance assessment of university teachers chiefly includes the following aspects, (1) one is explicit content: ① Whether teaching materials (teaching plan, teaching schedule, internship plan, graduation design materials, course construction, examination papers, etc.) are submitted timely and correctly; ② Classroom teaching tasks: the completion of teaching workload; ③ Guidance of students' practical teaching, including: competition awards, patent application, paper publication, etc.; (2) The other is implicit content: ① Teaching quality: teaching attitude, teaching methods, teaching effect, etc.; ② Cultivation of students' innovation ability, consciousness, etc.; ③ Participation in teaching research activities: discipline construction, formulation of talent training program, declaration of teaching research topics, participation in teaching transformation, etc.; ④ of Relevant examination papers: such as the examination paper, standard scoring procedure, the integrity of invigilation information; ⑤ Creation of teacher ethics. The explicit evaluation content can be directly assessed in a quantitative way, but which is improper for implicit content. In this regard, the objective evaluation is conducted by transforming the qualitative content into quantitative assessment based on the fuzzy comprehensive evaluation method.

#### **4.3 Determination of the Weight Value of Teaching Performance Indicators**

In order to carry out objective evaluation of teaching performance, the weight value of each indicator

should also be reasonably determined by authoritative professors with abundant teaching and management experience, such as, supervision expert, teaching administrator, Discipline leader and so on in addition to a comprehensive evaluation indicator system. According to the established indicator system, the Delphi method is adopted to determine the weight allocation of each indicator, that is, make the evaluation results consistent through several rounds of anonymous inquiries. Theoretically, the innovation capability of students

in practice should account for a large proportion, but given the objective evaluation information of students' innovation capability from the employment unit is inaccessible, and the comprehensive quality of students is the outcome of all teachers' efforts, the weight value of the corresponding indicator should not be overly high; Besides, the weight value of "formative results" in teachers' teaching activities should not relatively low as they are not the final form, as shown in Table 2.

Table 2. Work performance evaluation indicators

Primary indicator		Secondary indicator	Tertiary indicator
Teaching administrator	Practice teaching $U_1$ (0.25)	Submit teaching materials $U_{11}$ (0.35)	Complete material submission $U_{111}$ (0.35) Correct material submission $U_{112}$ (0.35) Timely material submission $U_{113}$ (0.30)
		Register examination results $U_{12}$ (0.20)	Test paper conforms to outline $U_{121}$ (0.45) Accurate score registration $U_{122}$ (0.55)
		Guide innovative practice $U_{12}$ (0.45)	Guide participating competitions $U_{41}$ (0.30) Guide paper publication $U_{42}$ (0.35) Guide patent application $U_{43}$ (0.35)
Student evaluation	Classroom teaching $U_2$ (0.15)	Rigorous teaching attitude $U_{21}$ (0.30) Plentiful teaching content $U_{22}$ (0.20) Reasonable teaching method $U_{23}$ (0.30) Obvious teaching effect $U_{24}$ (0.20)	
Discipline leader	Discipline construction $U_3$ (0.15)	Major and curriculum construction $U_{31}$ (0.35)	Premium courses creation $U_{311}$ (0.35) Professional brand Construction $U_{312}$ (0.35) Examination database construction $U_{313}$ (0.30)
		Team cooperation spirit $U_{32}$ (0.30)	
		Teaching research and communication $U_{33}$ (0.35)	Research project approval $U_{331}$ (0.35) Award-winning teaching results $U_{332}$ (0.35) Classroom teaching transformation $U_{33}$ (0.30)
Supervision expert	Classroom teaching $U_4$ (0.25)	Classroom teaching $U_{41}$ (0.45)	Teaching method $U_{411}$ (0.25) Language expression $U_{412}$ (0.25) Classroom atmosphere

			$U_{413}$ (0.25) Classroom interaction $U_{414}$ (0.25)
		Test paper quality $U_{42}$ (0.30)	Meet syllabus requirements $U_{421}$ (0.35) Appropriate questions in variety and quantity $U_{422}$ (0.25) Moderate difficulty $U_{423}$ (0.25) Accurate and independent $U_{424}$ (0.15)
		Standard scoring procedure $U_{43}$ (0.25)	
Teacher self-evaluation	Comprehensive factors $U_5$ (0.10)	Classroom teaching $U_{51}$ (0.25) Practice teaching $U_{52}$ (0.25) Discipline construction $U_{53}$ (0.25) Teaching research $U_{54}$ (0.25)	
Employment unit	Practical capability $U_6$ (0.10)	Problem discovery ability $U_{61}$ (0.35) Problem solving ability $U_{62}$ (0.35) Practical innovation ability $U_{63}$ (0.30)	

The assessment indicators of all the participating teachers are scored according to the teaching performance evaluation indicator system in the early stage, and the assessment subjects based on the corresponding proportions of lecturers, associate professors, professors and so on, and the comprehensive fuzzy assessment list is obtained, as shown in Table 3.

Table 3. Comprehensive assessment list of teaching performance

Indicator	Teacher Zhao	Teacher Li	Teacher Sun	Teacher Wang
Complete material submission	0.87	0.92	0.85	0.94
Correct material submission	0.82	0.93	0.83	0.85
Timely material submission	0.85	0.78	0.80	0.81
Test paper conforms to outline	0.86	0.91	0.86	0.92
Accurate score registration	0.85	0.96	0.87	0.90
Guide participating competitions	0.89	0.90	0.86	0.83
Guide paper publication	0.85	0.86	0.80	0.81
Guide patent application	0.76	0.79	0.81	0.73
Rigorous teaching attitude	0.83	0.94	0.82	0.93
Plentiful teaching content	0.81	0.88	0.79	0.87
Reasonable teaching method	0.84	0.89	0.83	0.96
Obvious teaching effect	0.85	0.95	0.81	0.93
Premium courses creation	0.92	0.98	0.92	0.95
Professional brand Construction	0.87	0.93	0.86	0.89
Examination database construction	0.97	0.89	0.94	0.96
Team cooperation spirit	0.74	0.77	0.78	0.81

Research project approval	0.79	0.88	0.75	0.82
Award-winning teaching results	0.86	0.81	0.87	0.83
Classroom teaching transformation	0.78	0.79	0.86	0.80
Teaching method	0.88	0.90	0.85	0.83
Language expression	0.85	0.91	0.93	0.89
Classroom atmosphere	0.82	0.88	0.83	0.87
Classroom interaction	0.88	0.93	0.88	0.94
Meet syllabus requirements	0.89	0.87	0.91	0.92
Appropriate questions in variety and quantity	0.91	0.92	0.88	0.85
Moderate difficulty	0.84	0.89	0.80	0.87
Accurate and independent	0.91	0.86	0.92	0.81
Standard scoring procedures	0.81	0.82	0.91	0.85
Classroom teaching	0.85	0.81	0.78	0.82
Practical teaching	0.96	0.87	0.86	0.91
Discipline construction	0.91	0.94	0.96	0.92
Teaching research	0.94	0.90	0.94	0.90
Problem discovery ability	0.94	0.90	0.95	0.89
Problem solving ability	0.87	0.89	0.84	0.82
Practical innovation ability	0.81	0.87	0.85	0.82

## 5 THE CALCULATION OF FUZZY COMPREHENSIVE EVALUATION

### 5.1 Determination of Fuzzy Operator

The fuzzy comprehensive evaluation method is adopted to assess the teaching performance of university teachers. For sake of the rationality of evaluation and calculation process, the type of fuzzy operator should be properly determined. Each pair

of fuzzy operators represents different calculation methods, and the selection of assessment information shows certain tendency. Hence, the analysis is conducted on the information processing methods of several commonly-used fuzzy operators regarding reflection of weight role, adoption of R information, comprehensive degree and other aspects, so that the optimal operator type containing overall assessment information is determined, as shown in Table 4.

Table 4. Characteristics of each fuzzy operator

Characteristics	Fuzzy operator			
	$M(\wedge, v)$	$M(\bullet, v)$	$M(\wedge, +)$	$M(\bullet, +)$
Reflection of weight role	Not obvious	Obvious	Not obvious	Obvious
Comprehensive degree	Weak	Weak	Strong	Strong
Adoption of R information	Inadequate	Inadequate	Relatively adequate	Adequate
Type	Prominent main factor	Prominent main factor	Weighted mean	Weighted mean

The meaning of each symbol in the fuzzy operator: "+" means the add operation of ordinary real numbers; "•" is the multiply operation of ordinary real numbers; "∧" and "v" represent

minimum (min) and maximum (max) operations respectively.

(1) Fuzzy operator  $M(\wedge, v)$ , the mathematical model is shown in equation (5). In the process of fuzzy calculation, only the indicator factors with the



largest membership degree  $r_{d,ij}$  and major role are taken into consideration, while the minor indicators are not considered, thus excluding the influence of other factors.

$$b_{d,j} = \vee \left( a_{d,j} \wedge_{i=1}^m r_{d,ij} \right), j = 1, 2, \dots, n \quad (5)$$

Where:  $a_{d,j}$  measures the role of  $u_{d,j}$  in assessment factors;

$b_{d,j}$  represents the membership degree of  $v_{d,j}$  to fuzzy subset  $B_d$ ;

$$b_{d,j} = \sum_{i=1}^m a_{d,i} r_{d,ij}, j = 1, 2, \dots, n$$

$r_{d,ij}$  means that the assessment object belongs to the membership degree of the evaluation level  $v_{d,j}$  when solely considering  $u_{d,j}$ .

(2) Fuzzy operator  $M(\bullet, +)$ , the mathematical model is shown in equation (6). The fuzzy operator is a matrix synthesis in line with the multiplication and addition arithmetic of ordinary real numbers, which can balance all indicators in weights, and fully reflect the information contained by all factors.

$$b_{d,j} = \sum_{i=1}^m a_{d,i} r_{d,ij}, j = 1, 2, \dots, n \quad (6)$$

(3) Fuzzy operator  $M(\bullet, \vee)$ , the mathematical model is shown in equation (7). Similar to  $M(\wedge, \vee)$ ,  $a_{d,i}$  only works to adjust the coefficient, thus the fuzzy operator also emphasizes the maximum operation of "v", which can't fully reflect the information of the assessment indicator.

$$b_{d,j} = \vee_{i=1}^m a_{d,i} r_{d,ij}, j = 1, 2, \dots, n \quad (7)$$

Based on the comparison of the information reflected by each fuzzy operator, the fuzzy operator  $M(\bullet, +)$  can clearly present the role of weight A, and ensure the full exertion of fuzzy relation matrix R information, so that effectively avoid the loss of teaching performance assessment information with relatively strong comprehensive characteristics. The operator  $M(\bullet, +)$  is finally selected as the mathematical model of fuzzy calculation to make sure the rationality of the whole process.

## 5.2 Determination of the Final Membership Degree

The evaluation indicator system of teaching performance is constructed in accordance with analytic hierarchy process, and each indicator is divided into several subsystems according to its attributes. The fuzzy comprehensive evaluation method is adopted in single-hierarchy calculation of each subsystem, then the final membership degree is determined by the calculation results, followed by the evaluation results of each assessment object. As shown in Table 2 and Table 3:  $U11 = \{ U111, U112, U113 \}$ , weight  $A11 = \{ 0.35, 0.35, 0.30 \}$ . On the basis of equation (2), the fuzzy relation matrix R11 composed of U11 indicators is constructed:

$$R_{11} = \begin{bmatrix} 0.87 & 0.92 & 0.85 & 0.94 \\ 0.82 & 0.93 & 0.83 & 0.85 \\ 0.85 & 0.78 & 0.80 & 0.81 \end{bmatrix}$$

Amid the U11 subsystem, allocate A11 and fuzzy relation matrix R11 in the light of the determined weight, conduct the fuzzy evaluation calculation of tertiary indicator with fuzzy operator  $M(\bullet, +)$  according to Equation (3):

$$\begin{aligned} B_{11} &= A_{11} \bullet R_{11} = \{0.35, 0.35, 0.30\} \bullet \begin{bmatrix} 0.87 & 0.92 & 0.85 & 0.94 \\ 0.82 & 0.93 & 0.83 & 0.85 \\ 0.85 & 0.78 & 0.80 & 0.81 \end{bmatrix} \\ &= (0.35 \times 0.87 + 0.35 \times 0.82 + 0.30 \times 0.85, \\ &\quad 0.35 \times 0.92 + 0.35 \times 0.93 + 0.30 \times 0.78, \\ &\quad 0.35 \times 0.85 + 0.35 \times 0.83 + 0.30 \times 0.80, \\ &\quad 0.35 \times 0.94 + 0.35 \times 0.85 + 0.30 \times 0.81) \\ &= (0.30 + 0.29 + 0.26, 0.32 + 0.33 + 0.23, \\ &\quad 0.30 + 0.29 + 0.24, 0.33 + 0.30 + 0.24) \\ &= (0.85, 0.88, 0.83, 0.87) \end{aligned}$$

According to the same calculation method:  $B12 = (0.86, 0.94, 0.87, 0.91)$ ;  $B13 = (0.84, 0.85, 0.82, 0.75)$ , based on the fuzzy relation matrix constructed by B11、B12、B13, conduct B1 secondary indicator fuzzy calculation, the results are as below:

$$\begin{aligned} B_1 &= A_1 \bullet R_1 = \{0.35, 0.20, 0.45\} \bullet \begin{bmatrix} 0.85 & 0.88 & 0.83 & 0.87 \\ 0.86 & 0.94 & 0.87 & 0.91 \\ 0.84 & 0.85 & 0.82 & 0.75 \end{bmatrix} \\ &= (0.35 \times 0.85 + 0.20 \times 0.86 + 0.45 \times 0.84, \\ &\quad 0.35 \times 0.88 + 0.20 \times 0.94 + 0.45 \times 0.85, \\ &\quad 0.35 \times 0.83 + 0.20 \times 0.87 + 0.45 \times 0.82, \\ &\quad 0.35 \times 0.87 + 0.20 \times 0.91 + 0.45 \times 0.75) \\ &= (0.85, 0.88, 0.83, 0.82) \end{aligned}$$

With the same fuzzy comprehensive calculation method, the single-hierarchy calculation results are obtained respectively as below:

$$\begin{aligned}
 B_1 &= (0.85, 0.88, 0.83, 0.82); \\
 B_2 &= (0.83, 0.92, 0.82, 0.93); \\
 B_3 &= (0.82, 0.85, 0.84, 0.86); \\
 B_4 &= (0.86, 0.88, 0.88, 0.87); \\
 B_5 &= (0.92, 0.89, 0.90, 0.90); \\
 B_6 &= (0.87, 0.89, 0.88, 0.85).
 \end{aligned}$$

Taking the calculation results of the single-hierarchy assessment as the relative membership degree matrix of the factor set U, the single-hierarchy fuzzy calculation model is applied again and calculated according to Equation (4), and the membership order of the teaching performance assessment under the overall indicator system is as follows:

$$U = \{U_1, U_2, U_3, U_4, U_5, U_6\}; A = \{A_1, A_2, A_3, A_4, A_5, A_6\}; B = \{B_1, B_2, B_3, B_4, B_5, B_6\}.$$

$$C = A \cdot B = A \cdot \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \end{bmatrix} = \{0.25, 0.15, 0.15, 0.25, 0.10, 0.10\} \cdot \begin{bmatrix} 0.85 & 0.88 & 0.83 & 0.82 \\ 0.83 & 0.92 & 0.82 & 0.93 \\ 0.82 & 0.85 & 0.84 & 0.86 \\ 0.86 & 0.88 & 0.88 & 0.87 \\ 0.92 & 0.89 & 0.90 & 0.90 \\ 0.87 & 0.89 & 0.88 & 0.85 \end{bmatrix}$$

$$= (0.87, 0.91, 0.88, 0.90)$$

The teaching performance evaluation results of all teachers are ranked according to the final membership degree: Teacher Li, Teacher Wang, Teacher Sun, Teacher Zhao, namely, Teacher Li obtains the highest teaching performance.

## 6 THE FORMULATION OF IMPROVEMENT MEASURES

The teaching performance assessment of university teachers is the catalyst of higher education reform. The effective feedback of assessment information to relevant teachers is the only way to address the targeted problems appearing in teaching activities. Hence, colleges and universities should establish a two-way feedback mechanism inside and outside school to continuously enhance the teaching performance.

### 6.1 Feedback to Assessment Teachers

College teachers, as a group of high intelligence, usually have higher cognitive competence, whose work is more driven by internal motivation. Thus, the feedback from a multi-dimensional perspective can make teachers have reflection and internal consciousness, then cope with the problems existing in their teaching activities, so that realize the primary function of performance evaluation. Furthermore, the ultimate purpose of teaching performance assessment is not ranking, but to build

a scientific and reasonable internal incentive mechanism and an impartial competition environment through evaluation, so as to stimulate teachers' awareness of carrying out teaching transformation and constantly improve their teaching performance.

### 6.2 Improve Formative Evaluation Content

In addition to final evaluation, the teaching performance evaluation should also include formative evaluation. The overall mastery of teachers' performance and achievements in the teaching process is crucial to conduct objective evaluation, and the "teaching archive" will provide powerful support for the evaluation. The so-called "teaching archive" refers to the long-term, planned and purposeful tracking records of teachers' teaching process and results, as the prototype record of teachers in teaching activities, it is a information summary based on multiple evaluation methods including teachers' self-evaluation, which sums up the comprehensive materials reflecting teachers' teaching status and quality. Moreover, the assessment objects should adhere to the principles of comprehensiveness, accuracy and authenticity in establishing teaching archives.

### 6.3 Establish Tracking Feedback Mechanism

The major task of college teachers is to impart scientific knowledge and spiritual wealth into students' knowledge, skills and morality, and make them grow into compound talents that realize individual value while satisfy economic and social development demands. Hence, students' practical innovation ability should be involved in the teaching performance evaluation of college teachers. The establishment of graduate tracking mechanism can effectively combine teaching activities with the needs of economic growth and social progress, in which the concept of "adaptability" advocated by higher education is embodied in the teaching performance assessment, so as to better address the disconnection between talent training and social demands.

### 6.4 Formulate Performance Evaluation and Incentive Mechanism

The formulation of university teacher teaching performance evaluation incentive model relies on

the recognition of the evaluation system and results. Accordingly, in addition to a scientific and reasonable teaching performance evaluation system, universities are supposed to establish a multilevel incentive mechanism to stimulate teachers' enthusiasm and creativity in work, thus both achieving their goal of personal value and school expectations, while realizing the benign cycle of higher teaching level brought by teaching performance evaluation, as shown in Fig. 3.

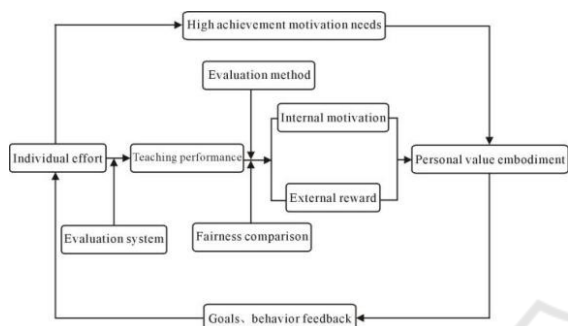


Figure.3. Incentive model of teaching performance evaluation

## 7 CONCLUSION

In order to obtain objective results in the teaching performance assessment of college teachers and further motivate their teaching activities, this paper puts forward the method based on fuzzy comprehensive evaluation. Through the analysis on the factors involved in the teaching activities, the evaluation indicator system is established with hierarchy analysis method containing explicit and implicit content. Besides, the formative evaluation content in teaching activities and innovation capability of the students in practice are incorporated into the evaluation system; The optimal type of fuzzy operator is determined on the basis of analysis and comparison, which make the whole calculation process more rational; The improvement measures are proposed according to the final assessment results, aiming to achieve the benign cycle of higher teaching level and teaching performance evaluation. Nevertheless, there is a lack of effective assessment methods for the evaluation of students' innovation capability in practice, and the content involved in the formative evaluation calls for more definition. In this regard, the above limitations should be taken into consideration in further research.

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## REFERENCES

- Butt Babar Zaheer, Rehman Kashifur. A study examining the students Satisfaction in Higher Education [J]. *Procedia Social and Behavioral Sciences*, 2010(2):5446-5450.
- CHEN Ming-xue. Reflection and Practice Direction on University Teachers' Teaching Evaluation [J]. *Heilongjiang Researches on Higher Education*, 2017, 281(9): 56-59.
- DUAN Meng-chang, DENG Zheng-cai, SHEN Zhi. An analysis and Countermeasures of College Experiment Teaching Evaluation on Current Situation [J]. *Journal of Higher Education Research*, 2013, 36(4): 49-51.
- GAO Wei, LI Rui-chen, SONG Shuo-qi. Research and Enlightenment of the Classroom Observation Protocols for Undergraduate STEM (COPUS) in American Universities [J]. *Journal of Higher Education Research*, 2020, 43(2):66-74.
- GEN NIPNAEV. Peer assessment for learning from a social perspective: the influence of interpersonal variables and structural features [J]. *Educational research review*, 2009, 4 (1): 41-54.
- Kember David. Characterizing a teaching and learning environment conducive to making demands on students while not making their workload excessive [J]. *Studies in Higher Education*, 2006, 31(2):185-198.
- Kenneth Akiha. What Types of instructional shifts Do students experience investigating active learning in science, Technology, engineering, and Math classes across Key Transition Points from Middle school to the University level [J]. *Frontiers in Education*, 2018(2): 1-18.
- LI Fu-xing, CHEN Liang. The Application Research of Fuzzy Comprehensive Synthetic in the Evaluation Optimization Choice of the Motorcycle [J]. *PACKAGING NGINEERING*, 2015, 36(08):87-91.
- LIU Xiao-ying, ZHANG Jian. Comprehensive Evaluation on Teaching Quality Based on Extension Theory [J]. *Chongqing Technol Business Univ. (Nat Sci Ed)*, 2014, 31(10):71-77.
- Liu Zhi-yong, Zhu Ling. Research of Evaluation on University Teaching Quality Information Feedback Mechanism [J]. *JOURNAL OF TAISHAN UNIVERSITY*, 2013, 35(2):134-138.
- MA Hui-mei. The Philosophy Method Research of University Teachers' Teaching Evaluation [J]. *Heilongjiang Researches on Higher Education*, 2019, 302(6):39-42.
- Smith M K, Vinson E L, Smith J A, etc. A campus -wide study of STEM courses: new perspectives on teaching practices and perceptions [J]. *CBE Life Sciences Education*, 2014(4):624-635.

- Smith M K, Jones F H M, Gilbert S L, etc. The Classroom Observation Protocol for Undergraduate STEM (COPUS): a new instrument to characterize university STEM classroom practices [J]. CBE life sciences education, 2013(4) :618-627.
- SUN Chun-hua. Study of Comprehensive Evaluation for Teaching Quality in Colleges and Universities based on Multi-level Analytic Hierarchy Process [J]. Journal of Inner Mongolia University of Finance and Economics, 2015, 13(1):107-110.
- Zhao Qing-rong. China University Teaching Feedback Evaluation Orientation Reflection [J]. China Higher Education Research, 2013(3):102-106.
- ZHAO Chun-yuan. Application of fuzzy judgment based on AHP model in the evaluation of teaching quality [J]. Journal of Shenyang Institute of Engineering (Natural Science), 2011, 7(2): 185-189.

