EDUCATIONAL SCIENCES: THEORY & PRACTICE eISSN: 2148-7561, ISSN: 2630-5984

Received: 29 December 2023
Revision received: 23 March 2024
Accepted: 10 April 2024

www.jestp.com

DOI 10.12738/jestp.2024.1.013♦ **January** 2024 ♦ 24(1) ♦ 165-181

Article

The Utilization of Fuzzy Analytic Hierarchy Process for Evaluating Teacher Performance in Chinese Universities

Shaodong Geng*
Faculty of Management,Universiti of Technologi Malaysia, 81310 UTM, Johor Bahru,Johor,Malaysia.
Email: gengshaodong@graduate.utm.my

Siti Rahmah Awang
Faculty of Management,Universiti of Technologi Malaysia, 81310 UTM, Johor Bahru,Johor,Malaysia.
Email: sitirahmah@utm.my

Tahir Ahmad
Fellow, Malaysian Mathematical Sciences Society, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia. Email: tahirahmad12376@gmail.com

Ahmad Bathaei
Faculty of Management,Universiti of Technologi Malaysia, 81310 UTM, Johor Bahru,Johor,Malaysia.
Email: bathaei.ahmad@graduate.utm.my

Abstract

This study examines the complex challenges involved in evaluating university faculty performance, including the absence of a comprehensive evaluation index system, the limited diversity of evaluative perspectives, and the dominance of qualitative over quantitative measures. To address these limitations, we propose a performance evaluation model utilizing the Fuzzy Analytic Hierarchy Process (FAHP). This model structures a hierarchical framework for faculty performance indicators and employs FAHP to assign weights to each indicator, thereby enhancing measurement precision. The fuzzy judgment method is then used to integrate both qualitative and quantitative data into a unified evaluation metric. Empirical testing of the model confirms its ability to deliver a thorough, accurate, and reliable assessment of faculty performance. Findings demonstrate a strong alignment between qualitative insights and quantitative outcomes, underscoring the model's validity. This study offers a valuable contribution to the scientific and nuanced management of faculty performance in higher education contexts.

Keywords

University Teachers, Performance Evaluation, Fuzzy Analytic Hierarchy Process.

Correspondence to Shaodong Geng, Faculty of Management,Universiti of Technologi Malaysia, 81310 UTM, Johor Bahru,Johor,Malaysia.
Email: gengshaodong@graduate.utm.my

Citation: Geng, S. D., Awang, S. R., Ahmad, T., Bathaei, A. (2024). The Utilization of Fuzzy Analytic Hierarchy Process for Evaluating Teacher Performance in Chinese Universities. *Educational Sciences: Theory and Practice, 24*(1), 165 - 181.
http://dx.doi.org/10.12738/jestp.2024.1.013

Since the turn of the century, the scale and international competitiveness of China's higher education system have seen significant growth. Concurrently, competition among higher education institutions has intensified (Fan et al., 2023). As a result, enhancing core competitiveness has become a central issue in higher education management. This core competitiveness is reflected not only in knowledge dissemination and talent cultivation but also in scientific research capacity and quality. The key element underpinning these competitive advantages is the faculty. The comprehensive quality and overall strength of the teaching staff are essential for the sustainable development of colleges and universities (Horng et al., 2020). Thus, establishing an effective performance evaluation system for teachers, which motivates them to enhance their overall quality, talent development, and innovation in science and technology, is vital for the rapid growth of universities. Although various universities have implemented several evaluation measures in teaching, research, and other areas, these programs are often fragmented and lack cohesion, leading to less-than-ideal outcomes (Goldring & Schuermann, 2009).

The performance characteristics of university teachers are a crucial aspect of human resource management, addressing the high mobility and concentration of faculty members. Effectively evaluating university teachers and developing classification policies are significant challenges in managing academic talent. Western scholars stress the importance of understanding the unique traits and essence of academic professionals in evaluation processes. However, in order to comply with the development requirements of universities in the new era, we must find a more perfect teacher performance evaluation model (Al-Maqrashi et al., 2023). First of all, university teachers have become an important source of social and economic value creation and a key contributing factor to university performance; Second, the evaluation system of university teachers needs to be further improved (Zhao, Lynch Jr, & Chen, 2010). Relevant studies have confirmed that the turnover rate of university teachers is much higher than that of ordinary employees. One of the important reasons for their resignation is that their work achievements are not respected and recognized; Third, the quantitative methods of University Teachers' work need to be strengthened. Most of the existing evaluation methods emphasize the integrity and cannot effectively classify and identify university teachers, which is difficult to meet the actual situation of the diversity of university teachers (Giannikas, 2021).

The main point of our concern and reflection is to explore the comprehensive, accurate and motivating evaluation method for the core competencies of teachers. A good evaluation method should take full account of the expertise of different teachers, and teachers who have made outstanding achievements in teaching, research and other service work should be highly evaluated in the system. Therefore, the complexity and multifaceted nature of teacher evaluation determines that it is a multi-level and multi-indicator evaluation decision-making problem (Yan, 2019). In this paper, through the Fuzzy Analytic Hierarchy Process (FAHP), the elements always related to decision-making are decomposed into objectives, criteria, alternatives and other levels to make the subjective judgment process mathematical, thinking, while encompassing the uncertainty of the cognition of the thing, to establish a more objective and comprehensive performance evaluation system (Qi, 2022).

Methodology

FAHP was proposed by Zhang (2018), an American scholar. It uses a combination of qualitative analysis and quantitative analysis for comprehensive judgment. It has more in-depth and perfect conclusions for quantitative index judgment, and can put forward more detailed conclusions for relevant research, which has been widely used in all aspects of society. In the process of analysis, a diversified and multi-level analysis method is established, and each influencing element in the analysis object is compared one by one to ensure the accuracy of the analysis results (Röst & Sadeghimanesh, 2021). The establishment of the analysis matrix can accurately understand the relationship between the various elements, and accurately judge the correlation according to the relationship between the upper and lower stages. Combining quantitative analysis with qualitative analysis, the relevance of various elements in the object is calculated and sorted according to the relevance, which provides a reference for the final research results.

Analytic Hierarchy Process (AHP)

First of all, it is necessary to clarify the ultimate goal to be achieved by the object of study, and then decompose the object of study into different constituent factors according to its own nature, external environment, and path of realization. Since there are interactions and influences between the constituent factors, all the constituent factors can be clustered and combined according to the affiliation relationship to form a multidimensional and multilevel analytical structural model (Wu et al., 2022). Based on people's judgment of the actual situation and objective factors, each level of factors in the model is assigned a weight to quantify the relative importance of all the constituent factors for the total goal. Finally, through the comprehensive calculation between the matrix set, the combined weight value is obtained, which serves as the basis for the evaluation results (Sun & Asmawi, 2023).

Main steps of AHP

(1) Hierarchy Structure

Selecting appropriate performance evaluation elements for university teachers is a crucial and challenging aspect of personnel management in colleges and universities (Wang & Jiang, 2023). Evaluating teachers' ethics, teaching, research, and social service contributions is highly complex. The diversity in disciplines, specialties, research outputs, forms, timelines, and comprehension levels makes it challenging to establish a universally applicable standard for scientifically evaluating teachers' performance. Since teachers' performance evaluation is inherently relative (Choi, Kim, & Kim, 2018), it is essential to consider the relativity and multidimensionality of their perf20ormance comprehensively. This approach helps avoid absolutism and one-sidedness when choosing evaluation elements (Eremina, Smolin, & Martyshina, 2022). The performance evaluation criteria for university teachers consist of four primary categories: (a) Teacher ethics, which include their role in teaching and mentoring students as well as their moral integrity; (b) Teaching, which covers aspects such as teaching workload, quality of instruction, development of textbooks, and student evaluations; (c) Scientific research, which considers original research achievements, the number and quality of research projects, and the number and quality of published papers; (d) Social service, which involve participation in various public welfare activities within the school and the community, as well as their standing in the academic community. Based on the university's standards for teacher quality, there are four tables could be constructed as follows:

Table 1: *Evaluation Elements for Teacher Ethic.*

Criteria Level	Alternatives level	Secondary Alternatives Level
Teachers Ethic A_1	Teaching and Educating People B_1	Career Passion C_1
		Care for Students C_2
	Moral Integrity B_2	Professional Ethics C_3
		Personality C_4

Table 2: *Evaluation Elements for Teaching.*

Criteria Level	Alternatives Level	Secondary Alternatives Level
Teaching A_2	Teaching Workload B_3	Teaching Time C_5
		Curriculum Design Guidance C_6
		Social Practice Guidance C_7
		Graduation Design Guidance C_8
	Teaching Quality B_4	Students' Evaluation C_9
		Teaching Supervision C_{10}

		Teachers' Mutual Evaluation C_{11}
		Superior Evaluation C_{12}
		Teaching Topic C_{13}
	Teaching Reform and Results B_5	Teaching Reform Paper C_{14}
		Textbook Construction C_{15}
		Teaching Methods C_{16}
		Prize of Teaching C_{17}
		Quality Course Construction C_{18}

Table 3: *Evaluation Elements of Scientific Research.*

Criteria level	Alternatives level	Secondary Alternatives Level
Scientific Research A_3	Science and Technology Awards B_6	National level C_{19}
		Provincial and Ministerial Level C_{20}
		Municipal Bureau Level S_{21}
	Papers and Monographs B_7	SSCI,SCI C_{22}
		EI,CSSCI C_{23}
		ISTP C_{24}
		Monographs C_{25}
	Research Project B_8	National Social Science Foundation C_{26}
		Other National Foundation C_{27}
		Number of Provincial and Ministerial Projects C_{28}
		Number of Projects below Provincial and Ministerial Level C_{29}
		Number of Projects Identification C_{30}
		Total Scientific Research Funds C_{31}
		Invention Patent C_{32}

Table 4: *Evaluation Elements of Social Service.*

Criteria Level	Alternatives Level	Secondary Alternatives Level
Social Service A_4	Social Activities B_9	Public Benefit Activities C_{33}
		Social Reputation C_{34}
	Academic Reputation B_{10}	Academic Status C_{35}
		Academic Influence C_{36}

Based on the performance evaluation elements outlined in Table 1-4, a conceptual framework has been developed, as illustrated in Figure 1. The performance evaluation elements for university teachers are categorized into criteria elements, alternatives elements, and secondary alternatives elements. At the first level, the elements are divided into four main categories: Teachers' Ethics, Teaching, Scientific Research, and Social Service.

Teachers' Ethics: This category includes aspects such as teaching and educating students, along with moral integrity.
Teaching: This encompasses factors like teaching workload, student evaluations, teaching quality, and topics related to teaching.
Scientific Research: This involves components such as science and technology awards, publishing papers and monographs, and research projects.
Social Service: This includes participation in social activities and maintaining an academic reputation.

This structured framework ensures a comprehensive evaluation of university teachers' performance across multiple dimensions.

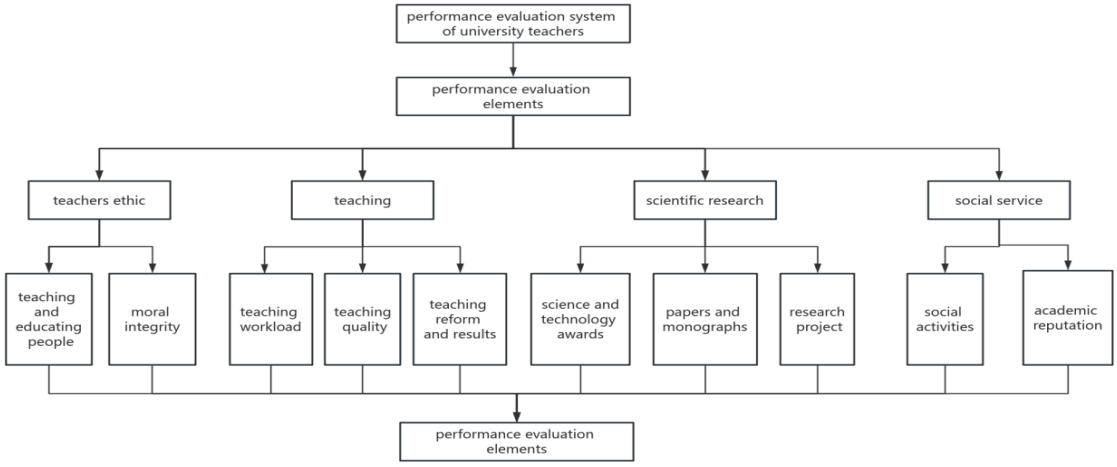

Figure 1: *The Framework of Teacher Performance Evaluation.*
(Due to the Numerous Secondary Alternative Elements, they are not listed in Figure 1)

(2) Comparison Matrix

A comparison matrix is used to measure the relative importance between two elements (Zhao & Li, 2023). It represents the importance of the horizontal elements in relation to the elements. Based on varying degrees of relative importance, values are assigned on a scale from 1 to 9 (Zhai, 2023).

Table 5: *Scale Meaning.*

Scale	Meaning
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Values
Reciprocal	Values for Inverse Comparison

(3) Consistency Check

When comparing the importance of two elements, subjective judgments can lead to inconsistencies, especially when multiple elements are involved. To avoid logical contradictions in the comparison matrix, a consistency check is necessary. For instance, if one judges that A > B (A is more important than B), B > C, and C > A (which contradicts common sense, as A should be more important than C), a logical contradiction arises. Therefore, it is essential to test the consistency of the importance assigned to various elements (Zhang, 2022).

In a consistent matrix A, the following relationship should hold:

$$a_{ij}a_{jk} = a_{ik}, \forall i, j, k = 1,2, \dots, n \quad (1)$$

In practical comparisons, achieving complete consistency in the logical equations of the pairwise comparison matrix is often unattainable due to the multitude of elements involved. Therefore, a certain level of inconsistency is permissible, requiring only a degree of consistency. To quantify the inconsistency of the pairwise comparison matrix A (an n>1 square matrix), the consistency index (CI) is introduced:

$$CI = \frac{\lambda_{max}}{n-1} \quad (2)$$

Where$\lambda_{max}$the eigenvalue of matrix A, and n is the number of elements.

The index RI is introduced to gauge the magnitude of CI. RI represents the average value of consistency indices from numerous same-order, random reciprocal matrices, and can be determined by consulting Table 6.

Table 6: *The Value of RI.*

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Calculate the random consistency ratio (CR) using the formula to determine if the consistency of the pairwise comparison matrix A meets the necessary requirements:

$$CR = \frac{CI}{RI} \quad (3)$$

If the value$CR$is less than 0.1, it can be considered that there are no significant logical contradictions in the pairwise comparison matrix A, and the logical relationships within the data meet the requirements. Otherwise, a value greater than 0.1 indicates a significant logical contradiction, which could impact the final judgment. In such cases, it is necessary to adjust the pairwise comparison matrix A (Yang & Ma, 2007).

(4) Overall Prioritization and Consistency Check

The overall prioritization involves calculating the weights representing the relative importance of all factors at a specific hierarchy level with respect to the goal level (the top level) (Becker, Eigenfeld, & Kerpes, 2023). Firstly, prioritize the factors within a specific hierarchy and test the logical consistency by comparing the alternative level against the criteria level using the consistency indexCI_j (where j=1,2,...m). Then, compute the consistency ratio for the overall hierarchical prioritization:

$$CR = \frac{a_1CI_1 + a_2CI_2 + \cdots + a_mCI_m}{a_1RI_1 + a_2RI_2 + \cdots + a_mRI_m} \quad (4)$$

If$CR$is less than 0.1, it indicates that there are no significant inconsistencies in the hierarchical ranking, and the logical consistency meets the required standards, thus passing the test. If$CR$is greater than 0.1, adjustments should be made until$CR$is less than 0.1.

Fuzzy Judgement

Due to their inherent characteristics, some evaluation indicators have unclear boundaries and are difficult to quantify, such as "more" and "less" or "fast" and "slow". By synthesizing fuzzy relationships, these factors can be quantified, and a comprehensive evaluation can then be conducted based on the degree of membership.

Main Steps

(1) Building the Set of Evaluation Elements

When evaluating the target object, various influencing elements are involved. These elements are compiled into a set, known as the elements set, typically denoted by $E, E = (E_1, E_2, \dots, E_m)$. In Chapter 2.1.1 of this study, 36 elements have been selected, forming the elements set $E, E = (E_1, E_2, \dots, E_{36})$.

(2) Establishing the Comment Set of Experts

The fuzzy evaluation method addresses the subjectivity inherent in the analytic hierarchy process, simplifying the judgment process and making it more scientific and reasonable (Deng, 2023). Once the weights of each element have been determined using AHP, the next step is to create a fuzzy comment set, represented by $M, M = (M_1, M_2, \dots, M_n)$, $3 \le n \le 8$,. The comment set used in this paper is $M = (M_1, M_2, \dots, M_5)$, as illustrated in Table 7 below.

Table 7: *Comment Set.*

	$\mathbf{M_1}$	$\mathbf{M_2}$	$\mathbf{M_3}$	$\mathbf{M_4}$	$\mathbf{M_5}$
Comment	Excellent	Good	Merit	Qualified	Unqualified
Score	100-90	89-80	79-70	69-60	Below 59

(3) Determining the Membership Function and Fuzzy Matrix

This study employs the membership function for comprehensive operations and classification, which is a critical component of the fuzzy comprehensive evaluation. In the membership function $F_i^s(x)$, x_i represents the average score given by experts. The boundary division of evaluation scores is determined by combining the contents listed in Table 7 of the comment set. In this paper, the comprehensive evaluation results are categorized into five grades, with boundary values of 100, 90, 80, 70 and 60 respectively. Consequently, the corresponding function formula for each evaluation element is derived as follows:

$$F_i^1(x) = \begin{cases} 1, x_{ij} \ge 100 \\ \dfrac{x_i - 90}{10,90} < \ x_{ij} \le 100 \\ 0, x_{ij} < 90 \end{cases}$$

$$F_i^2(x) = \begin{cases} 0, x_{ij} > 100 \ or \ x_{ij} \le 80 \\ \dfrac{x_i - 80}{10}, \quad 80 < x_{ij} \le 90 \\ \dfrac{100 - x_i}{10}, 90 < x_{ij} < 100 \end{cases}$$

$$F_i^3(x) = \begin{cases} 0, x_{ij} > 90 \ or \ x_{ij} \le 70 \\ \dfrac{x_i - 70}{10}, \quad 70 < x_{ij} \le 80 \\ \dfrac{90 - x_i}{10}, 80 < x_{ij} \le 90 \end{cases} \tag{5}$$

$$F_i^4(x) = \begin{cases} 0, x_{ij} > 80 \ or \ x_{ij} \le 60 \\ \dfrac{x_i - 60}{10}, \quad 60 < x_{ij} \le 70 \\ \dfrac{80 - x_i}{10}, 70 < x_{ij} \le 80 \end{cases}$$

$$F_i^5(x) = \begin{cases} 0, x_{ij} > 70 \\ \dfrac{70 - x_i}{10,60} < x_{ij} \le 70 \\ 1, x_{ij} < 60 \end{cases}$$

After the calculations, multiply the determined membership vector$F$by their respective weights$W$. This yields the fuzzy judgment matrix$Q_i$at each level. Similarly, we can obtain the comprehensive fuzzy judgment matrix$Q$for all levels as follows:

$$Q_i = \sum_{j}^{m} F_i^s(x_{ij}) W_i \tag{6}$$

Finally, according to the principle of maximum membership, determine the value of $\max_{1\le s\le 5}\{Q_i\} = Q_i$nd find the corresponding comment by referencing the comment set in Table 7 to determine the comprehensive results of university teacher performance.

Results

In line with the evaluation method requirements of this study, Hebei Finance University in China was selected as a case study. A total of 38 questionnaires were distributed to teachers from various faculties, with different professional titles and areas of expertise, ranging in age from 25 to 60.

Data Analysis

(1) First, we begin with the criteria level. Using the data collected from 38 respondents, pairwise comparisons were conducted on teachers' ethics, teaching, scientific research, and social services.

The comparison matrix can be constructed as follows:

$$C_1 = \begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} \\ A_{21} & A_{22} & A_{23} & A_{24} \\ A_{31} & A_{32} & A_{33} & A_{34} \\ A_{41} & A_{42} & A_{43} & A_{44} \end{bmatrix} = \begin{bmatrix} 1 & 3 & 5 & 2 \\ \frac{1}{3} & 1 & 4 & \frac{1}{2} \\ \frac{1}{5} & \frac{1}{4} & 、 & \frac{1}{4} \\ \frac{1}{2} & 2 & 4 & 1 \end{bmatrix}$$

Next, calculate the sum of each column:

Table 8: *Sum of Column on Criteria level.*

Element	A_1	A_2	A_3	A_4
A_1	1	3	5	2
A_2	1/3	1	4	1/2
A_3	1/5	1/4	1	1/4
A_4	1/2	2	4	1
Sum of Column	2.03	6.25	14.00	3.75

To determine the prioritization, divide each value in the matrix by the sum of its respective column

Table 9: *Average of Rows at the Criteria Level.*

Element	A_1	A_2	A_3	A_4	Average
A_1	0.50	0.48	0.36	0.53	0.47
A_2	0.16	0.16	0.29	0.13	0.18
A_3	0.10	0.04	0.07	0.07	0.07
A_4	0.24	0.32	0.29	0.27	0.28
					1.00

Table 10: *Weight of Each Element.*

Criteria level	A_1	A_2	A_3	A_4
Weight	0.47	0.18	0.07	0.28

A consistency check is necessary to ensure the reliability of the comparison matrixC_1:

i. Calculating the consistency indexCI

$CI = \frac{\lambda_{max}}{n-1}$ calculate the eigenvalue of the comparison matrixC_1using python:

$$C_1 = \begin{bmatrix} 1 & 3 & 5 & 2 \\ \frac{1}{3} & 1 & 4 & \frac{1}{2} \\ \frac{1}{5} & \frac{1}{4} & 1 & \frac{1}{4} \\ \frac{1}{2} & 2 & 4 & 1 \end{bmatrix}$$

The outcome is:

ii. $\lambda \frac{4.098-4}{4-1}_{max}$rify the value of the corresponding random consistency indexRI

$$RI = 0.89$$

iii. Calculating the consistency ratioCR:

$$CR = \frac{CI}{RI} = \frac{0.033}{0.89} = 0.037 < 0.1$$

The result ofCRillustrates the consistency of$C_1$is acceptable.

Based on the questionnaires, the performance evaluation of teachers shows that the highest weight is given to teacher ethics, followed by social service. Teaching ranks third, and scientific research is given the least consideration. By applying a similar method, the weight of each element at the alternative level could be obtained.

(2) Analysis of weights of elements B_1, B_2onA_1,B_3, B_4, B_5onA_2,B_6, B_7, B_8on$A_3$and $B_9, B_{"10}$" onA_4

The comparison matrices$C_2, C_3, C_4, C_5$are

$$C_2 = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ \frac{1}{2} & 1 \end{bmatrix}$$

$$C_3 = \begin{bmatrix} B_{33} & B_{34} & B_{35} \\ B_{43} & B_{44} & B_{45} \\ B_{53} & B_{54} & B_{55} \end{bmatrix} = \begin{bmatrix} 1 & 4 & 3 \\ \frac{1}{4} & 1 & \frac{1}{2} \\ \frac{1}{3} & 2 & 1 \end{bmatrix}$$

$$C_4 = \begin{bmatrix} B_{66} & B_{67} & B_{68} \\ B_{76} & B_{77} & B_{78} \\ B_{86} & B_{87} & B_{88} \end{bmatrix} = \begin{bmatrix} 1 & 5 & 3 \\ \frac{1}{5} & 1 & \frac{1}{4} \\ \frac{1}{3} & 4 & 1 \end{bmatrix}$$

$$C_5 = \begin{bmatrix} B_{99} & B_{9,10} \\ B_{10,9} & B_{10,10} \end{bmatrix} = \begin{bmatrix} 1 & \frac{1}{3} \\ 3 & 1 \end{bmatrix}$$

The weights of each element on $A_1, A_2, A_3, A_4$are summarized at Table 11:

Table 11: *The Weights of each Element on Alternative Level.*

$\mathbf{A_1}$	$\mathbf{B_1}$	$\mathbf{B_2}$	**None**
Weight	0.67	0.33	None
A_2	B_3	B_4	B_5
Weight	0.62	0.14	0.24
A_3	B_6	B_7	B_8
Weight	0.62	0.10	0.28
A_4	$B_{9,10}$	$B_{10,10}$	None
Weight	0.25	0.75	None

The consistency ratio$CR$for each A_1, A_2, A_3, A_4also can be calculated as in Table 12:

Table 12: *The Results of CRofA_1, A_2, A_3, A_4.*

	$\mathbf{A_1}$	$\mathbf{A_2}$	$\mathbf{A_3}$	$\mathbf{A_4}$
CR	0	0.0176	0.0825	0

Therefore, in the evaluation of teacher ethics, it is generally believed that teaching and educating students are more important than moral integrity. Regarding teaching, the teaching workload is considered the most important, followed by teaching reform and results, with teaching quality ranked third. In the realm of scientific research, science and technology awards are deemed the most crucial, followed by research projects, and then papers and monographs. For social service, academic reputation is considered more important than social activities.

(3) The results of normalizing the weights of each element of the secondary alternatives at the secondary level are presented below:

Table 13: *The Influence of Secondary Alternatives Level Elements on the Alternatives-Level Elements.*

Alternatives Level	Secondary Alternatives Level	Weight
B_1	C_1	0.503
	C_2	0.497
B_2	C_3	0.506
	C_4	0.494
B	C_5	0.245
	C_6	0.269
	C_7	0.244
	C_8	0.242
	C_9	0.251
B_4	C_{10}	0.255
	C_{11}	0.265
	C_{12}	0.229
	C_{13}	0.148
	C_{14}	0.161
B_5	C_{15}	0.172
	C_{16}	0.179
	C_{17}	0.169
	C_{18}	0.171
	C_{19}	0.263
B_6	C_{20}	0.323
	C_{21}	0.414
	C_{22}	0.244
B_7	C_{23}	0.292
	C_{24}	0.331
	C_{25}	0.133
	C_{26}	0.113
	C_{27}	0.122
	C_{28}	0.130
B_8	C_{29}	0.136
	C_{30}	0.16
	C_{31}	0.162
	C_{32}	0.177
B_9	C_{33}	0.410
	C_{34}	0.590
B_{10}	C_{35}	0.489
	C_{36}	0.511

(4) Constructing the Performance Evaluation System

From steps (1) to (3), the weights of elements at each level have already been quantified. Therefore, the evaluation system can be easily calculated as shown in the following Table 14:

Table 14: *The Performance Evaluation System.*

Criteria Level	Alternatives Level	Secondary Alternatives Level	Weight in Goal Level	Ranking
A_1(0.47)	B_1(0.67)	C_1(0.503)	0.1583947	1
		C_2(0.497)	0.1565053	2
	B_2(0.33)	C_3(0.506)	0.0784806	5
		C_4(0.496)	0.0766194	6
	B_3(0.62)	C_5(0.245)	0.027342	10
		C_6(0.269)	0.0300204	8
		C_7(0.244)	0.0272304	11
		C_8(0.242)	0.0270072	12
A_2(0.18)	B_4(0.14)	C_9(0.251)	0.0063252	24
		C_{10}(0.255)	0.006426	22
		C_{11}(0.365)	0.006678	21
		C_{12}(0.229)	0.0057708	25
	B_5(0.24)	C_{13}(0.148)	0.0063936	23
		C_{14}(0.161)	0.0069552	20
		C_{15}(0.172)	0.0074304	17
		C_{16}(0.179)	0.0077328	16
	B_6(0.62)	C_{17}(0.169)	0.0073008	19
		C_{18}(0.171)	0.0073872	18
		C_{19}(0.263)	0.0114142	15
		C_{20}(0.323)	0.0140182	14
		C_{21}(0.414)	0.0179676	13
A_3(0.07)	B_7(0.10)	C_{22}(0.244)	0.001708	35
		C_{23}(0.292)	0.002044	34
		C_{24}(0.331)	0.002317	32
	B_8(0.28)	C_{25}(0.133)	0.000931	36
		C_{26}(0.113)	0.0022148	33
		C_{27}(0.122)	0.0023912	31
		C_{28}(0.130)	0.002548	30
		C_{29}(0.136)	0.0026656	29
		C_{30}(0.160)	0.003136	28
		C_{31}(0.162)	0.0031752	27
		C_{32}(0.177)	0.0034692	26
A_4(0.28)	B_9(0.25)	C_{33}(0.410)	0.0287	9
		C_{34}(0.590)	0.0413	7
	B_{10}(0.75)	C_{35}(0.489)	0.10269	4
		C_{36}(0.511)	0.10731	3

Creating a bar chart of the weights for each element clearly illustrates which elements have the greatest impact on teacher performance.

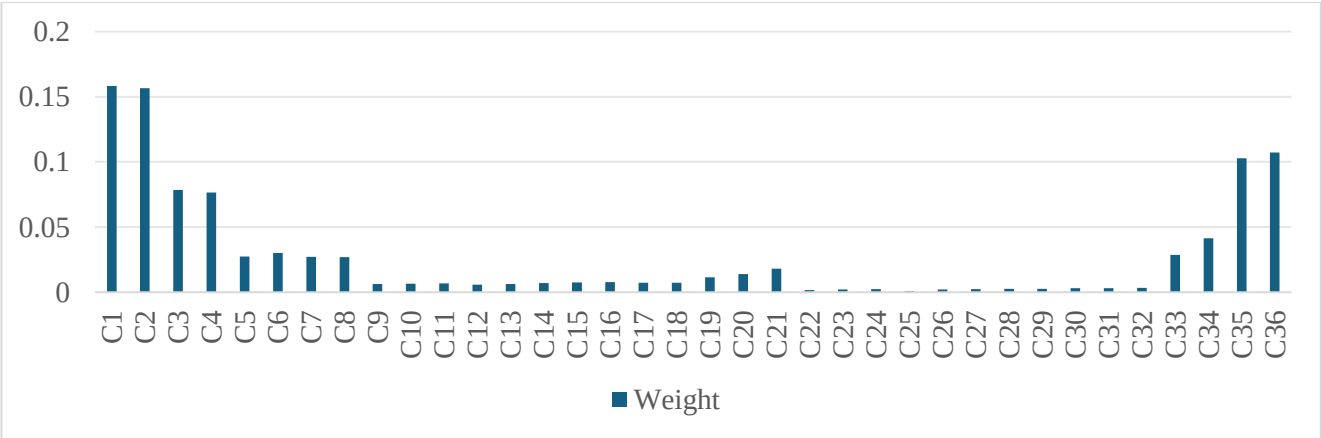

Figure 2: *Weight of Each Element.*

(5) Fuzzy Judgement

In this study, a panel of 10 leaders from Hebei Finance University was assembled to assess and score each element of the performance evaluation system. The resulting average scores for each element are detailed below:

Table 15: *Average Score of Each Element.*

Criteria Level	Secondary Alternatives Level	Mean Value
A_1	C_1	83
	C_2	91
	C_3	93
	C_4	86
	C_5	55
	C_6	88
	C_7	88
	C_8	63
	C_9	50
A_2	C_{10}	74
	C_{11}	78
	C_{12}	82
	C_{13}	87
	C_{14}	54
	C_{15}	84
	C_{16}	62
	C_{17}	55
	C_{18}	51
	C_{19}	58
	C_{20}	91
	C_{21}	61
	C_{22}	74
	C_{23}	53
	C_{24}	77
A_3	C_{25}	64
	C_{26}	60
	C_{27}	88
	C_{28}	63
	C_{29}	91
	C_{30}	91
	C_{31}	92
	C_{32}	50
	C_{33}	77
C_4	C_{34}	87
	C_{35}	91
	C_{36}	87

By applying formula (5), we can determine the membership vector for each element as shown:

$$F_1 = \begin{bmatrix} 0 & 0.3 & 0.7 & 0 & 0 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 \\ 0 & 0.6 & 0.4 & 0 & 0 \end{bmatrix}$$

$$F_2 = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0.8 & 0.2 & 0 & 0 \\ 0 & 0.8 & 0.2 & 0 & 0 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0.4 & 0.6 & 0 \\ 0 & 0 & 0.8 & 0.2 & 0 \\ 0 & 0.2 & 0.8 & 0 & 0 \\ 0 & 0.7 & 0.3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0.4 & 0.6 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$F_3 = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.1 & 0.9 \\ 0 & 0 & 0.4 & 0.6 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0.7 & 0.3 & 0 \\ 0 & 0 & 0 & 0.4 & 0.6 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0.8 & 0.2 & 0 & 0 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$F_4 = \begin{bmatrix} 0 & 0 & 0.7 & 0.3 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0.1 & 0.9 & 0 & 0 & 0 \\ 0 & 0.7 & 0.3 & 0 & 0 \end{bmatrix}$$

Then, the total membership vector is

$$F = \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \end{bmatrix}$$

As shown in Table 14, the weights for each element have been established. The ultimate result of fuzzy judgement matrix is shown as following:

$$Q = W \times U = (0.05208073, 0.562423, 0.239336,\ \ 0.028103, 0.118057)$$

Therefore theQ_{max}n the basis of the grading of the comments in the comment set provided in Table 7, it can be concluded that the teacher performance evaluation system established by HFU using FAHP is good.

Discussion

The teacher performance evaluation system at Hebei Finance University has been significantly enhanced after being improved by the Fuzzy Analytic Hierarchy Process (FAHP). This demonstrates the advancement and superiority of this research, providing Hebei Finance University with a more accurate evaluation method that is widely recognized and accepted by the majority of the teachers. The final results of the FAHP-based evaluation system demonstrate its excellence in handling the complexity and fuzziness of teacher performance evaluation in Chinese universities. The system comprehensively considers various elements of teacher performance and provides a relatively accurate evaluation outcome. The FAHP system quantifies evaluators' subjective feelings using fuzzy numbers, which allows the evaluation results to better reflect the actual performance levels of teachers. The model's effectiveness has also been well-validated through multiple consistency tests. From the research process, it can be seen that FAHP processes data by first conducting hierarchical analysis followed by fuzzy judgment. Both AHP and fuzzy mathematics have strong theoretical support in their respective fields, providing a robust theoretical foundation for the implementation of FAHP. After thoroughly comparing the relationships and weight allocations between pairs of elements, the system has constructed a logical and scientifically-oriented evaluation process, making the model highly feasible both theoretically and practically. Traditional evaluation methods often struggle with subjective assessments and uncertain data, but FAHP demonstrates uniqueness and superiority in handling these situations, significantly enhancing data processing capabilities. The FAHP system is capable of considering a wide range of evaluation elements by integrating data from diverse sources and in diverse forms, and giving comprehensive evaluation results. The evaluation results provided by the FAHP system are quantitative, which makes it easy for

managers to compare and analyse the results so as to make more scientific decisions. Based on the evaluation results, the system can provide administrators with specific improvement suggestions and measures to help them make more targeted decisions on teacher training and resource allocation. The transparency of the evaluation process and results of the model can enhance the transparency and fairness of the decision-making process and help to increase the trust and acceptance of the evaluation results by both management and teachers.

Overall Results

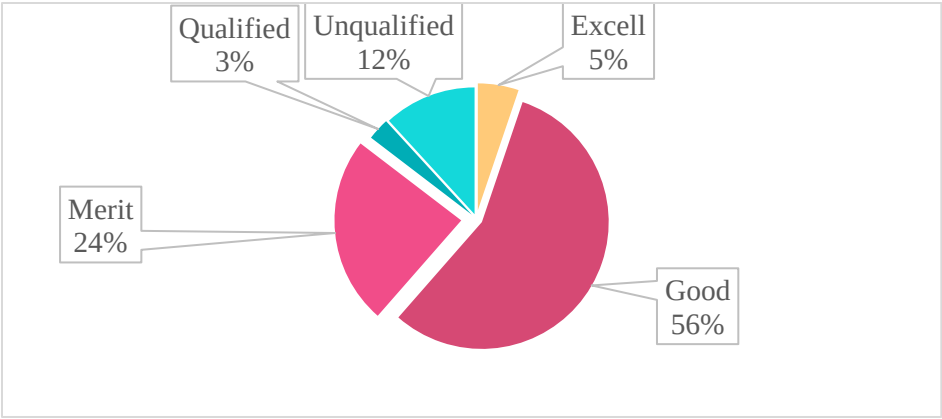

Figure 3: *The Comments of Teacher Performance Evaluation System.*

Based on the previous results, the FAHP-based teacher performance evaluation system at HFU has shown good performance, achieving the research objectives and providing an effective and accurate evaluation method. This system deals with the complexity and fuzziness of teacher evaluation, reflects the multi-dimensional characteristics of teacher performance, and obtains reasonable evaluation results. The system quantifies the subjective judgment by fuzzy number, which improves the accuracy of the evaluation. Consistency test ensures the logic and consistency of the judgment, and improves the effectiveness of the model. FAHP method combines analytic hierarchy process and fuzzy mathematics, has a solid theoretical foundation, can effectively deal with uncertain data, integrate data from different sources for comprehensive evaluation. The system's dynamic updating capability allows it to adjust evaluation results promptly based on the latest data, maintaining the real-time nature and accuracy of the evaluations. The evaluation results are quantitative, making it easier for managers

to compare and analyse the results for more scientific decision-making. Additionally, the transparency of the model enhances the trust and acceptance of the evaluation results among management and teachers.

Weight of each Element on Criteria Level

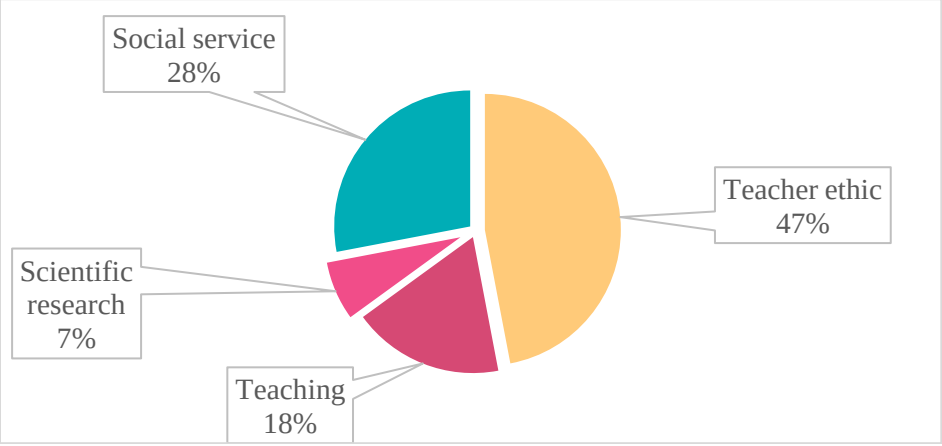

Figure 4: *The Proportion of each Element at Criteria Level.*

Due to the elements of the alternative level and second alternative level often changing as a result of changes in university development goals, this paper mainly examines the impact of the four elements at the criteria level. The fact that the university places teachers' ethics at the top of its performance evaluation indicates that it highly values the moral character and professional conduct of teachers, considering these to be the most important qualities of a teacher. This reflects the university's focus on cultivating teachers with good moral qualities and professionalism and emphasizes the moral function of education. Social service ranks second, showing that the university not only pays attention to teachers' performance within the university but also emphasizes their contributions to society. This reflects the university's encouragement for teachers to actively participate in social services, fulfil their social responsibilities, expand the outreach of education, and promote interaction and integration between the university and society. Teaching ranked third in terms of results, but it was still a key factor in the assessment. This shows that the school recognizes the importance of teaching quality to the cultivation of students, and hopes that teachers will invest enough energy and resources in teaching to ensure the teaching effect and the learning quality of students. Research is ranked fourth, indicating that while research is also an important component of teacher performance, it has a lower relative weight in the university's evaluation system than teacher ethics, social service and teaching. This may reflect that universities currently place more emphasis on the overall quality of faculty and their contribution to society, rather than just academic research results. This ranking order reflects the philosophy that universities are well-rounded in faculty performance evaluations. This shows that after teachers have teacher ethic, they should also pay attention to social service and teaching of students. For universities, scientific research, although very important, is not the only criterion for every university.

Suggestions for Building Good Teachers Team in China

In the performance evaluation system for university teachers constructed using FAHP, the highest-ranked indicator is teachers' professional ethics, followed by social service, with teaching ability and research work ranking third and fourth, respectively. This prioritization reflects universities' strong emphasis on the overall quality of faculty and their expectations for teachers' development. Based on these findings, Chinese universities can implement specific measures to cultivate a high-quality educational team. To strengthen the construction of teacher ethics, universities should conduct regular activities that promote teachers' moral education, acknowledge exemplary teachers' achievements, and establish clear standards for teacher ethics, including defined reward and punishment mechanisms. Institutions should incentivize faculty involvement in public welfare and volunteer services, fostering a heightened sense of social responsibility and dedication. To enhance social service awareness and capabilities, universities can encourage teachers to participate in social service projects that leverage their professional knowledge to address societal issues. This involvement should include collaborations with communities and initiatives that promote the practical application of research results. Recognizing and rewarding

teachers who excel in social service will inspire broader participation, strengthen the institution's social influence, and deepen faculty commitment to community engagement. Improving teaching innovation and quality is also essential. Teachers should be encouraged to adopt innovative strategies, refine classroom teaching quality, modernize curriculum content, and embrace diverse teaching methods that support students' all-around development. Regular assessments of teaching quality, coupled with student feedback, will guide continual optimization of teaching methods. Establishing a dedicated teaching research fund will support faculty in pursuing innovative teaching projects and developing their teaching skills further. Finally, promoting scientific research involves increasing investment in research resources, enhancing research conditions, and fostering an environment conducive to high-quality research. Universities should encourage interdisciplinary collaboration to broaden and deepen research outcomes. Faculty should also be motivated to apply their research to real-world problems, accelerating the transformation of technological achievements and contributing to societal progress. By adopting these strategies, Chinese universities can more effectively assess and enhance the comprehensive quality of their faculty, ensuring ongoing improvements in the quality of education and teaching.

Limitations, Future Research and Conclusion

Although the construction of FAHP teacher performance evaluation system has strong advantages, it is also accompanied by the limitations of its research. Respondents often have this subconscious bias when comparing elements to determine their weight and importance arrangement. We should include a variety of research-related populations in the study, such as students and peers, to improve the stability and inclusiveness of the overall model. In addition, this study should pay more attention to the compatibility of the performance evaluation system with the long-term development goals of schools. Using FAHP can establish a multilevel evaluation system for college teachers' performance evaluation. By establishing the corresponding elements and guidelines, this paper transforms the problem of comprehensive evaluation of teachers' performance into a quantitative mathematical model. According to the strategic development orientation of Hebei Finance University, the evaluation elements as well as the relative weight relationship between the elements are given. It is worth noting that the Hebei Finance University's developmental orientation is typical of Chinese universities. Compared with the previous evaluation system, the introduction of fuzzy theory improves the fault tolerance of the evaluation system and makes the evaluation results more scientific and objective. From the data analysis, it can be seen that the performance evaluation system proposed in this paper has strong operability, sufficient theoretical basis, and the assessment results are more reasonable. The evaluation results can effectively reflect the achievements made by teachers for the development of the university, teachers with different specialties can achieve higher evaluation scores under the evaluation system, and teachers who are in line with the strategic development of the university and have made outstanding achievements can be highly recognized under the appraisal system. In addition, the evaluation system can maximize the motivation and potential of teachers, which is conducive to achieving the goal of rapid and steady development of colleges and universities. Finally, decision makers can revise the relative importance weights of the evaluation elements to realize the dynamic adjustment of the performance evaluation system according to their own positioning and strategic adjustments.

Reference

Al-Maqrashi, K., Al-Musalhi, F., Elmojtaba, I., & Al-Salti, N. (2023). Mathematical Analysis and Parameter Estimation of a Two-Patch Zika Model. *Letters in Biomathematics, 10*(1), 29-41. https://doi.org/10.30707/LiB10.1.1682014077.806265

Becker, M., Eigenfeld, R., & Kerpes, T. (2023). Understanding the Commercialization of Intellectual Property Patents in Europe: Highlighting Implications and Regulations for the Biotechnology Sector. *Journal of Commercial Biotechnology, 28*(1), 252-264. https://doi.org/10.5912/jcb1902

Choi, E. H., Kim, E.-K., & Kim, P. B. (2018). Effects of the Educational Leadership of Nursing Unit Managers on Team Effectiveness: Mediating Effects of Organizational Communication. *Asian Nursing Research, 12*(2), 99-105. https://doi.org/10.1016/j.anr.2018.03.001

Deng, J. (2023). A Multimodal Discourse Analysis of Posters-Based on Visual Grammar. *International Journal of Linguistics, 15*(6), 165-173. https://doi.org/10.5296/ijl.v15i6.21560

Eremina, G., Smolin, A., & Martyshina, I. (2022). Convergence Analysis and Validation of a Discrete Element Model of the Human Lumbar Spine. *Reports in Mechanical Engineering, 3*(1), 62-70. https://doi.org/10.31181/rme200103062e

Fan, L., Xie, C., Zhang, J., Huang, S. S., & Wang, X. A. (2023). Hotel Digital Capability: Dimensionality and Measurement. *Journal of Hospitality and Tourism Management, 57*, 225-235. https://doi.org/10.1016/j.jhtm.2023.10.010

Giannikas, C. N. (2021). Performance Assessment in Teacher Education Programs: Direct Evaluation of Teaching Ability. In M. D. Ramírez-Verdugo & B. Otcu-Grillman (Eds.), *Interdisciplinary Approaches Toward Enhancing Teacher Education* (pp. 258-273). IGI Global. https://doi.org/10.4018/978-1-7998-4697-0.ch014

Goldring, E., & Schuermann, P. (2009). The Changing Context of K–12 Education Administration: Consequences for Ed.D. Program Design and Delivery. *Peabody Journal of Education, 84*(1), 9-43. https://doi.org/10.1080/01619560802679583

Horng, J.-S., Liu, C.-H., Chou, S.-F., & Huang, Y.-C. (2020). The Roles of University Education in Promoting Students' Passion for Learning, Knowledge Management and Entrepreneurialism. *Journal of Hospitality and Tourism Management, 44*, 162-170. https://doi.org/10.1016/j.jhtm.2020.06.005

Qi, F. F. (2022). Visual Narrative Study of Traditional Art in China's Original Picture Books Under Multimodal Discourse Analysis. *Publishing Science, 30*(03), 43-50. https://doi.org/10.3969/j.issn.1009-5853.2022.03.006

Röst, G., & Sadeghimanesh, A. (2021). Unidirectional Migration of Populations with Allee Effect. *Letters in Biomathematics, 10*(1), 43-52. https://doi.org/10.30707/LiB10.1.1682014077.816387

Sun, L., & Asmawi, A. (2023). The Effect of WeChat-Based Instruction on Chinese EFL Undergraduates' Business English Writing Performance. *International Journal of Instruction, 16*(1), 43-60. https://doi.org/10.29333/iji.2023.1613a

Wang, W., & Jiang, L. (2023). Writing on WeChat Moments: Impact on Writing Performance and Learner Autonomy. *Computer Assisted Language Learning, 36*(7), 1236-1264. https://doi.org/10.1080/09588221.2021.1976799

Wu, F., Wang, Z., Song, D., & Lian, H. (2022). Lightweight Design of Control Arm Combining Load Path Analysis and Biological Characteristics. *Reports in Mechanical Engineering, 3*(1), 71-82. https://doi.org/10.31181/rme2001210122w

Yan, L. (2019). A Study on WeChat-Based Collaborative Learning in College English Writing. *English Language Teaching, 12*(6), 1-9. https://doi.org/10.5539/elt.v12n6p1

Yang, H. T., & Ma, D. T. (2007). Research on Consistency of Judgment Matrix in Analytic Hierarchy Process. *Modern Electronic Technology, 19*, 46-48. https://doi.org/10.3969/j.issn.1004-373X.2007.19.015

Zhai, C. (2023). RETRACTED: Practical research on college English vocabulary teaching with mobile technology. *International Journal of Electrical Engineering & Education, 60*(1_suppl), 3481-3494. https://doi.org/10.1177/0020720920985057

Zhang, J. X. (2018). The Connotation and Essential Features of Performance Evaluation of Talent Cultivation in Colleges and Universities. *Educational Research, 39*(03), 55-61. https://www.cqvip.com/qk/96925x/201803/675206877.html

Zhang, Y. (2022). A Mixed-Methods Study of Computer-Mediated Communication Paired With Instruction on EFL Learners' Pragmatic Competence. *International Journal of Computer-Assisted Language Learning and Teaching (IJCALLT), 12*(1), 1-14. https://doi.org/10.4018/IJCALLT.291113

Zhao, X., & Li, N. (2023). Biological Genomics-Driven Pathway Analysis in Modern Nursing. *Journal of Commercial Biotechnology, 28*(3), 212-219. https://doi.org/10.5912/jcb1592

Zhao, X., Lynch Jr, J. G., & Chen, Q. (2010). Reconsidering Baron and Kenny: Myths and Truths about Mediation Analysis. *Journal of Consumer Research, 37*(2), 197-206. https://doi.org/10.1086/651257