A multilevel fuzzy analysis model of higher education teaching quality

Hao Xiaofang[1*], Zhang Yuhong[1], Li Guolin[1]

[1] *College of Education, Hebei Normal University of Science &Technology, Qinhuangdao, Hebei, P.R.China,066004*

Received 1 October 2014, www.cmnt.lv

Abstract

To improve the overall quality of teachers and enhance the teaching ability as well as the teaching quality of institutes of higher learning for the purpose of nurturing high-tech talents, this paper proposes a multilevel fuzzy analysis model of higher education teaching quality based on fuzzy system theory. It constructs a multilevel evaluation system and acquires the fuzzy evaluation set of teaching quality and fuzzy value of a quantity. Through calculation we can get the fuzzy membership between teaching quality and fuzzy evaluation set. Fuzzy membership is applied to standardization according to different types and scales of indicators to get the integrated weighted fuzzy membership. This will realize the evaluation on teaching quality of institutes of higher learning and helps to increase the overall quality of teachers. A case study is introduced to prove the efficacy of the model and the algorithm.

Keywords: higher education; teaching quality; fuzzy analysis; multiple attribute decision making; evaluation model

1 Introduction

With the development of science and technology, modern society has yearning for high-tech talents. Teachers of institutes of higher learning play an important role in promoting the overall quality of high-tech talents. Management on teaching quality is given priority by the school as teaching becomes the most essential task. Therefore, it is significant to carry out a multilevel evaluation on teaching quality and standardize management on teaching in order to increase the efficiency and improve the quality of the school. Meanwhile, it also serves as guidance for teachers to improve their teaching ability [1-3].

Many scholars and experts have already studied the teaching quality of higher education and registered some achievements in terms of the evaluation system and evaluation method [4-8]. Based on previous researches and the fuzzy mathematic theory [9-12], this paper proposes an improved multilevel evaluation system of teaching quality of higher education. It constructs a multilevel fuzzy analysis model through fuzzy evaluation set and fuzzy membership of different indicators.

2 Multilevel evaluation system of the teaching quality of higher education

Teaching quality of higher education is mainly presented in two perspectives. One is the teacher's ability to impart knowledge. The other is student's ability to learn and apply knowledge. This paper focuses on whether the evaluation is scientific, objective, with target and reasonable based on surveys and tailored to real situation. It constructs a three-layer evaluation system, namely, the system layer, the criterion layer and the indicator layer. The system layer consists of five perspectives: teaching quality, teaching ability, student's learning ability, student's research ability and student's other ability. The layers and the indicators are shown in Table 1.

TABLE 1 Multilevel evaluation system of the teaching quality of higher education

system layer	criterion layer	indicator layer	Type of indicator
Evaluation system of the teaching quality of higher education C	Teaching quality C_1	Professional knowledge c_{11}	qualitative indicator
		Course planning c_{12}	qualitative indicator
		Classroom teaching effect c_{13}	qualitative indicator
		Advanced teaching method c_{14}	qualitative indicator
	Teaching ability C_2	Project number c_{21}	quantitative indicator

[*] ***Corresponding author's*** e-mail: 67896246@qq.com

Evaluation system of the teaching quality of higher education C	Teaching ability C_2	Number of papers c_{22}	quantitative indicator
		Number of awards c_{23}	quantitative indicator
		Number of researches c_{24}	quantitative indicator
	Student's learning ability C_3	Professional knowledge learning ability c_{31}	qualitative indicator
		Creativity c_{32}	qualitative indicator
		Practice ability c_{33}	qualitative indicator
		Proportion of award c_{34}	quantitative indicator
	Student's research ability C_4	Number of participations in scientific and technological design c_{41}	quantitative indicator
		Number of awards for scientific and technological design c_{42}	quantitative indicator
		Number of patent application and papers c_{43}	quantitative indicator
	Student's other ability C_5	Training on expanding ability c_{51}	qualitative indicator
		Training on environmental adaptability c_{52}	qualitative indicator
		Training on the ability to solve problems independently c_{53}	qualitative indicator

3 A multilevel fuzzy analysis model of higher education teaching quality

3.1 MULTILEVEL EVALUATION SET OF HIGHER EDUCATION TEACHING QUALITY

The analysis of teaching quality of higher education is a complicated decision-making process. It requires a reasonable description and effective measurement of all evaluation results, which indicates the necessity to have a multilevel evaluation set. Therefore, we divide the teaching quality into five grades and the evaluation set is expressed as:

$$U = \{U_1, U_2, U_3, U_4, U_5\} \tag{1}$$

In the expression, refers to excellence, refers to good, refers to medium, refers to pass and refers to fail.

There are two types of evaluation, the qualitative and the quantitative ones. This paper discusses them respectively. For qualitative indicators, we can get the membership degree through fuzzy membership function.

$$\varphi_i^j = f_{U_i^j}\left(v(x_i) \otimes \left[v_{min}\left(U_i^j\right), v_{max}\left(U_i^j\right)\right]\right) \tag{2}$$

In the expression, the membership degree of qualitative indicator is shown as Table 2.

TABLE 2 Value of fuzzy membership of qualitative indicator

membership φ_i	Explanation of qualitative indicator
0	No membership
0.2	Poor membership
0.4	Membership
0.6	Good membership
0.8	Fair membership
1.0	Absolute membership
0.1, 0.3, 0.5, 0.7, 0.9	In between

If it is a quantitative evaluation indicator, the calculation of fuzzy membership refers to 3.3 based on fuzzy distance

3.2 WEIGHT ALLOCATION OF MULTILEVEL EVALUATION INDICATORS OF TEACHING QUALITY

Many indicators need to be taken into account in the evaluation as they have different influence on teaching quality. Traditional AHP, through capable of acquiring the weight of indicators [13], is subjective in the course of producing weight. Therefore, this paper adopts an indicator negotiation weighing method based on AHP to be more objective.

Suppose an expert uses 1-9 ratio scale to evaluate indicator. The acquired weight of indicator according to AHP is and fits and. The negotiated weight of indicator is:

$$w_i^{\Theta} = \frac{1}{M}\sum_{p=1}^{M} w_i^p + \rho_i * \left| \max_{1 \le p \le M}\left(w_i^p\right) - \min_{1 \le p \le M}\left(w_i^p\right) \right| \tag{3}$$

In the expression, refers to the number of experts; refers to negotiation coefficient; is the number of evaluation indicators.

Then, the allocated model of weight of indicator is::

$$\overline{w_i} = \frac{w_i^{\Theta}}{\sum_{i=1}^{n_c} w_i^{\Theta}} \tag{4}$$

3.3 FUZZY MEMBERSHIP OF TEACHING QUALITY

Suppose the indicator c_i is a quantitative indicator, its value of a quantity is $V(c_i) = \left[v_{left}(c_i), v_{right}(c_i) \right]$.

If the ideal fuzzy value of a quantity field for teaching quality level j is $V^0(c_i) = \left[v_{left}^0(c_i), v_{right}^0(c_i) \right]$, then the fuzzy distance $D_i^j(P)$ between indicator c_i and teaching quality level j is

$$D_i^j(P) = \left(\left| v_{left}^0(c_i) - v_{left}(c_i) \right|^P + \left| v_{right}^0(c_i) - v_{right}(c_i) \right|^P \right)^{\frac{1}{P}} / 2^{\frac{1}{P}} \tag{5}$$

In particular, if $P=1$, the fuzzy distance is the Hamming distance. $D_i^j(1)$ Is expressed as:

$$D_i^j(1) = \left(\left| v_{left}^0(c_i) - v_{left}(c_i) \right| + \left| v_{right}^0(c_i) - v_{right}(c_i) \right| \right) / 2 \tag{6}$$

If $P=2$, the fuzzy distance is the Euclidean distance. $D_i^j(2)$ Is expressed as:

$$D_i^j(2) = \left(\left| v_{left}^0(c_i) - v_{left}(c_i) \right|^2 + \left| v_{right}^0(c_i) - v_{right}(c_i) \right|^2 \right)^{\frac{1}{2}} / \sqrt{2} \tag{7}$$

As quantitative indicator can be divided into positive and adverse indicators, they are equipped with different fuzzy distance. To unify the evaluation standard, we need to apply $D_i^j(P)$ to standardization.

If the quantitative indicator has positive distance, then the standardized fuzzy membership $\varphi_i^j(P)$ is:

$$\varphi_i^j(P) = \begin{cases} \dfrac{D_i^j(1) - \min\limits_{1 \le j \le N} \left(D_i^j(1) \right)}{\max\limits_{1 \le j \le N} \left(D_i^j(1) \right) - \min\limits_{1 \le j \le N} \left(D_i^j(1) \right)} & P=1 \\ \dfrac{D_i^j(2) - \min\limits_{1 \le j \le N} \left(D_i^j(2) \right)}{\max\limits_{1 \le j \le N} \left(D_i^j(2) \right) - \min\limits_{1 \le j \le N} \left(D_i^j(2) \right)} & P=2 \end{cases} \tag{8}$$

N refers to the number of teaching quality level.

If the quantitative indicator has adverse distance, then the standardized fuzzy membership $\varphi_i^j(P)$ is:

$$\varphi_i^j(P) = \begin{cases} \dfrac{\max\limits_{1 \le j \le N} \left(D_i^j(1) \right) - D_i^j(1)}{\max\limits_{1 \le j \le N} \left(D_i^j(1) \right) - \min\limits_{1 \le j \le N} \left(D_i^j(1) \right)} & P=1 \\ \dfrac{\max\limits_{1 \le j \le N} \left(D_i^j(2) \right) - D_i^j(2)}{\max\limits_{1 \le j \le N} \left(D_i^j(2) \right) - \min\limits_{1 \le j \le N} \left(D_i^j(2) \right)} & P=2 \end{cases} \tag{9}$$

According to the physical significance of the fuzzy distance, when indicator c_i of the evaluation object is closer to teaching quality level j, the fuzzy distance is smaller. When indicator c_i of the evaluation object is less close to teaching quality level j, the fuzzy distance is bigger.

Given that different evaluation indicator has different weight w_i, we can get the weighted fuzzy membership $\varphi_i^j(DL)$ between quantitative indicator c_i and teaching quality level j:

$$\varphi_i^j(DL) = \sum_{i=1}^{n_{c1}} \left(\overline{w_i} * \left(1 - \varphi_i^j(P) \right) \right). \tag{10}$$

In the expression, n_{c1} refers to the number of quantitative indicators in the same criterion layer.

Similarly, the weighted fuzzy membership $\varphi_i^j(DX)$ between qualitative indicator c_i and teaching quality level j:

$$\varphi_i^j(DX)=\sum_{i=1}^{n_{c2}}\left(\overline{w}_i * \varphi_i^j\right), \tag{11}$$

n the expression, n_{c2} refers to the number of qualitative indicator in the same criterion layer.

And there is $n_{c1}+n_{c2}=n_c$.

Therefore, the unified weighed fuzzy membership in the criterion layer is:

$$\varphi_i^j=\varphi_i^j(DL)+\varphi_i^j(DX)=\sum_{i=1}^{n_{c1}}\left(\overline{w}_i *\left(1-\varphi_i^j(P)\right)\right)+\sum_{i=1}^{n_{c2}}\left(\overline{w}_i * \varphi_i^j\right) \tag{12}$$

$$\varphi^j=\sum_{i=1}^{n_z}\left(w_i * \varphi_i^j\right) \tag{13}$$

In the expression, n_z refers to the number of criterion layer in the evaluation system.

According to optimization principle of fuzzy membership, when

$$\varphi^j=max\left(\varphi^1,\cdots,\varphi^k,\cdots,\varphi^N\right)=\varphi^t \tag{14}$$

It indicates that the evaluation object is the closest to teaching quality level t.

3.4 MODEL AND ALGORITHM

The multilevel fuzzy analysis model has the following steps:

Step 1: Construct the multilevel evaluation system for teaching quality of higher education according to Section 2. And get different evaluation sets according to Section 3.1.

Step 2: Use expression (3) and (4) to get different evaluation rules and weight of indicators according to Section 3.2.

Step 3: For qualitative indicators, get its fuzzy membership from Table 2;

Step 4: For quantitative indicators, use expression (5), (6) and (7) to get the fuzzy distance and then acquire the standardized fuzzy distance according to (8) and (9);

Step 5: Get the fuzzy membership between qualitative indicator and teaching quality level according to expression (10) to (12);

Step 6: Use expression (13) to get the integrated weighted fuzzy membership between evaluation object and teaching quality level. Use expression (14) to acquire the membership degree of the evaluation object based on integrated weighted fuzzy membership.

4 Case study and test

This paper takes teachers of an institute of higher learning as examples to prove the efficacy of the model and the algorithm. Through data collection, statistics and analysis and based on school policies and institutions, we have original data for teaching quality evaluation at hand. Teacher A is chosen as the example. Relevant information about qualitative indicator is shown in Table 3 and about quantitative indicator, Table 4.

TABLE 3 Qualitative indicator of teaching quality

criterion layer	weight	indicator layer	weight	fuzzy membership				
				Excellence	Good	Medium	Pass	Fail
C_1	0.314	c_{11}	0.25	0.70	0.85	0.30	0.10	0
		c_{12}	0.30	0.95	0.70	0.20	0.10	0
		c_{13}	0.30	0.85	0.80	0.40	0.20	0
		c_{14}	0.15	0.60	0.85	0.60	0.30	0
C_3	0.241	c_{31}	0.25	0.70	0.85	0.85	0.60	0
		c_{32}	0.20	0.40	0.60	0.80	0.60	0.30
		c_{33}	0.25	0.55	0.75	0.80	0.40	0.10
C_5	0.076	c_{51}	0.30	0.60	0.80	0.80	0.40	0
		c_{52}	0.30	0.60	0.85	0.75	0.30	0
		c_{53}	0.40	0.60	0.95	0.85	0.10	0

TABLE 4 Quantitative indicator of teaching quality

criterion layer	weight	indicator layer	weight	Ideal value of a quantity field of quantitative indicator					Value of a quantity
				Excellence	Good	Medium	Pass	Fail	Evaluation object
C_2	0.270	c_{21}	0.30	3-5	3	2	1	0	2
		c_{22}	0.25	5-10	3-5	2-3	1-2	0-1	4
		c_{23}	0.30	2-5	1-2	0-1	0-1	0	1
		c_{24}	0.15	6-10	4-6	2-4	0-2	0	3
C_3	0.241	c_{34}	0.30	0.45-1.00	0.30-0.45	0.15-0.30	0.05-0.15	0-0.05	0.35-0.40
C_4	0.099	c_{41}	0.30	5-10	3-5	1-3	0-1	0	2
		c_{42}	0.35	3-5	2-3	1-2	0-1	0	2
		c_{43}	0.35	8-15	6-8	4-6	2-4	0-2	10

Calculate the fuzzy distance
of the quantitative indicator in Table 4 according to Section 3.3.
The result is shown in Table 5.

TABLE 5 Fuzzy distance of quantitative indicator of teaching quality

indicator layer	Fuzzy distance of quantitative indicator				
	Excellence	Good	Medium	Pass	Fail
c_{21}	1.000	1.000	0	1.000	2.000
c_{22}	1.000	0	1.581	2.549	2.236
c_{23}	2.915	0	0.707	0.707	1.000
c_{24}	3.000	2.236	0	2.236	3.000
c_{34}	0.430	0.050	0.158	0.276	0.350
c_{41}	3.000	2.236	0	1.581	2.000
c_{42}	1.000	0	1.000	1.581	2.000
c_{43}	0	3.162	5.099	7.071	9.055

Standardize the fuzzy distance in Table 5
and the result is shown in Table 6

TABLE 6 Standardized fuzzy distance of quantitative indicator

indicator layer	Standardized fuzzy distance of quantitative indicator				
	Excellence	Good	Medium	Pass	Fail
c_{21}	0.500	0.500	1.000	0.500	0
c_{22}	0.608	1.000	0.380	0	0.123
c_{23}	0	1.000	0.757	0.757	0.657
c_{24}	0	0.255	1.000	0.255	0
c_{34}	0	1.000	0.716	0.405	0.211
c_{41}	0	0.255	1.000	0.473	0.333
c_{42}	0.500	1.000	0.500	0.210	0
c_{43}	1.000	0.651	0.437	0.219	0

Give weight to qualitative and quantitative indicator
and get the fuzzy membership of indicators, as is shown in Table 7

TABLE 7 Fuzzy memberships of indicators

Indicators	fuzzy membership				
	Excellence	Good	Medium	Pass	Fail
c_{11}	0.175	0.213	0.075	0.025	0
c_{12}	0.285	0.210	0.060	0.030	0
c_{13}	0.255	0.240	0.120	0.060	0
c_{14}	0.009	0.128	0.009	0.045	0
c_{21}	0.150	0.150	0.300	0.150	0
c_{22}	0.152	0.250	0.095	0	0.031
c_{23}	0	0.300	0.227	0.227	0.197
c_{24}	0	0.038	0.150	0.038	0
c_{31}	0.175	0.213	0.213	0.150	0
c_{32}	0.080	0.120	0.160	0.120	0.006
c_{33}	0.138	0.188	0.200	0.100	0.025
c_{34}	0	0.300	0.215	0.122	0.063
c_{41}	0	0.077	0.300	0.142	0.100
c_{42}	0.175	0.350	0.175	0.074	0
c_{43}	0.350	0.228	0.153	0.077	0
c_{51}	0.180	0.240	0.240	0.120	0
c_{52}	0.180	0.255	0.225	0.009	0
c_{53}	0.240	0.380	0.340	0.040	0

According to the fuzzy membership calculation model, we can get the comprehensive fuzzy membership sequence between teacher A and teaching quality level.

There is $\varphi = (0.501, 0.778, 0.607, 0.323, 0.094)$. Teacher A reached a good level in terms of teaching quality.

5 Conclusions

This paper proposes a multilevel fuzzy analysis model of higher education teaching quality based on fuzzy system theory. It constructs a multilevel evaluation system and acquires the weight of indicators and analyzes the fuzzy membership of qualitative and quantitative indicators. The integrated weighted fuzzy membership calculation model is given and the membership degree of teaching quality is confirmed based on fuzzy membership. It actually realizes the performance management of teaching quality of higher education on the computer.

References

[1] Wang Hong. China's higher education evaluation classification and realistic choice [J]. Higher education in China, 2011(7) : 44 -45.

[2] Xu Dehua, Chen Lihua. Exploration and practice of quantitative assessment of university teachers' performance [J]. China University Teaching 2009, (5):70-72.

[3] Yang Lijun,Dang Xin'an, Sheng Qiang, Xiao Lei. Practice Teaching Quality Assurance System for Engineering Personnel Based on QFD [J]. Research and Exploration in Laboratory, 2013,32(3):168-170+174.

[4] Zhou Xuzhang, Wang Caisheng, Caiyan. Construction of Practical Teaching System with Superior-quality Appliation-Oriented Engineering Talents [J]. Research and Exploration in Laboratory, 2010,29(12):125-127.

[5] Tao Yuwei, Xie Aijuan, Wang Juanling. Construction of Higher vocational education performance assessment system based on MHFCE [J]. Modern Education Science(Higher Education Research), 2013(5):167-169+172.

[6] Yu Shi. Evaluation of Teaching Quality Based on Fuzzy Analytic Hierarchy Process [J]. Computer Simulation, 2012,29 (6):369-372.

[7] Chen Kunbao. The Research of Teacher Teaching Quantity Evaluation Based on Fuzzy Theory [J]. MATHEMATICS IN PRACTICE AND THEORY, 2011 .41 (6) :72-78.

[8] Fu Haiyan, Fu Mousong, Zhang Chenyi. Application of rough set theory to instruction quality evaluation and analysis [J]. COMPUTER ENGINEERING AND APPLICATIONS, 2007. 43 (36) : 214-216.

[9] Sun Yanling, Ding Ning, Liang Yan. A Method of Teaching Quality Evaluation Making Use of BP Neural Networks [J]. COMPUTER SIMULATION, 2010.27(11):315-319.

[10]Bin Guangfu. New quantitative evaluation method of equipment state system field based on fuzzy analytic hierarchy process (ahp). System Engineering Theory and Practice [J].2010.30 (4) :744 -750.

[11] Rao Congjun, Xiao Xinping, Peng Jin. Novel combinatorial algorithm for the problems of fuzzy grey multi-attribute group decision making. Journal of Systems Engineering and Electronics ,2007, 18(4):774~780.

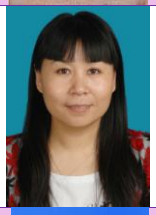
[12] Ti-chun Wang, Ai-jun Yang, Shi-sheng Zhong. MULTI-ATTRIBUTE EXTENSION FUZZY OPTIMIZED DECISION-MAKING MODEL OF SCHEME DESIGN. Tehnički vjesnik/Technical Gazette. 2014,21(2) : 239-247.

[13] Ding Yuehua. Constructing performance evaluation system for the ordinary colleges and universities based on AHP [J]. Communication of Finance and Accounting, 2013 (12):50-51

Authors

<Hao Xiaofang.>

She received her bachelor's degree of literature in Hebei Normal University, Baoding, Hebei. (2003), and master's degree of education in Hebei Normal University, Baoding, Hebei.(2006),Now she is a lecturer in Hebei Normal University of Science & Technology, Qinhuangdao, Hebei. Her major fields of study are education technology, vocational education, and information education.



<Zhang Yuhong>.

She received her bachelor's degree of education in Hebei Normal University of Science & Technology, Qinhuangdao, Hebei. (2001) and master's degree of education in Hebei Normal University, Baoding, Hebei. (2007), Now she is a lecturer in Hebei Normal University of Science & Technology, Qinhuangdao, Hebei. Her major fields of study are education technology, vocational education, and information education.

<Li Guolin>.

HE received his bachelor's degree of science in central china normal university, Wuhan, Hubei.(2003), and master's degree of engineering in Beijing University of Technology, Beijing.(2010). Now he is a lecturer in Hebei Normal University of Science & Technology, Qinhuangdao, Hebei. His major fields of study are education technology, information technology, and information education.