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Evaluation Research of College Experimental Teaching Based on the Theory of Fuzzy Mathematic and Analytic Hierarchy Process

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Abstract: Experimental teaching plays a more and more important role in the whole teaching system in colleges and universities. In the work points of the Ministry of education of 2013, implementation of the undergraduate engineering of teaching and construction of national experimental teaching demonstration center are both important aspects. In this study, the experimental teaching in the college is regarded as the research object and evaluated as an example. At first, this study builds up an evaluation index system of college experimental teaching from three aspects including the management, process and effect of the experimental teaching. And then a comprehensive algorithm model of evaluation is proposed by the means of the theory of fuzzy mathematics and Analytic Hierarchy Process and its application of the algorithm is tested with the specific data of experimental teaching in the college, which proves that the evaluation result of the model is consistent with the actual situation. Finally, the study puts forward some countermeasures and suggestions so as to improve the experimental teaching.

Key words: Fuzzy mathematics, analytic hierarchy process, experimental teaching, evaluation

INTRODUCTION

With the rapid development of higher education, the status of experimental teaching in the teaching system of the colleges and universities become more and more important in recent years. Experimental teaching is not only an important content of the whole teaching process in colleges and universities but also an important way to cultivate student's comprehensive quality and innovation ability. It plays the extremely important role in the cultivation of the students' ability to practice, analyze and solve problems independently (Xi *et al*., 2008).

Many scholars had made a lot of research about the experimental teaching (Antequera and Espinel, 2011; Balch, 2010; Pituch *et al*., 2009; Xia *et al*., 2007; Zheng and Shen, 2007), but there are seldom researches about the quantitative description of experimental teaching. According to the all-round, multi-angle requirements of experimental teaching and the actual situation of the university, the study tries to combine the qualitative method and quantitative method to make researches about experimental teaching. So, the study constructs a comprehensive quality evaluation model of experimental teaching and tests it with the specific data. Due to many factors involved in the evaluation of experimental teaching and it is difficult to quantify accurately the relationship among the indexes, this study introduces the theory of fuzzy mathematics and Analytic Hierarchy Process (AHP). The author makes good use of the advantages of two methods and combines them with the actual conditions of the experimental teaching evaluation. Finally, the study tries to build a set of index system to properly evaluate the experimental teaching of college teachers, improves the quality of personnel training, so as to promote the development of experimental teaching in colleges and universities.

THE CONSTRUCTION OF EVALUATION INDICATOR SYSTEM OF EXPERIMENTAL TEACHING

Evaluation indicator system of experimental teaching is an organic whole which is made up of a set of mutually linked and interacted indicators factor in accordance with a certain hierarchy. Evaluation indicator system is the link that combines the evaluation

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experts and evaluation objects (Liang, 2009). It is only to make comprehensive use of the evaluation system and indicators that the experimental teaching of college can be assessed as rationally as possible so as to promote the reform of experimental teaching. Sun and Cai (2009) took Shenzhen University in China as an example to study the present situation of experimental teaching, definition of evaluation, meaning of the construction of evaluation system, constructing principles of evaluation system and so on. Yue *et al.* (2010) started from the analysis of main problems existing in the experimental teaching, established the evaluation system of experimental teaching, so as to carry out the quality evaluation of experimental teaching. Xu (2007) proposed an open, pluralistic evaluation system of experimental teaching including six dimensions and expounds the main contents of evaluation of each dimension. Li *et al.* (2006) discussed the back ground, content and method about evaluating system of experimental teaching under the environment of information and provided a sample for it. Based on the above research, many scholars had made much valuable research about the evaluation of experimental teaching from different angles and different methods. After summarizing the above research results and referring to the index system, according to the actual situation of the school experimental teaching management development, the author tries to propose an evaluation indicator system which contains three first-level indicators, 14 second-level indicators (Table 1).

THE COMPREHENSIVE EVALUATION MODEL BASED ON THE THEORY OF FUZZY MATHEMATICS AND AHP

The Analytic Hierarchy Process(AHP) is an easy and functional decision process which was proposed and gradually improved by the American mathematician Saaty T.L. in the 1970's (Saaty, 1990). It can synthetically sort out the subjective judgment of people, combine the quantitative method and qualitative method and it is an effective method which is difficult to analyze with quantitative methods. The author combines it with the theory of fuzzy mathematics and qualifies the evaluation factors, finally the results of the experiment quality will be expressed by the quantitative value, whose main steps of application are as following (Jiang *et al*., 2009; Cao, 2008):

To conduct a multi-level analysis structure model: According to the correlation and subordinate relations among the indexes, a multi-level analysis structure model will be conducted via the clustering, in which the various factors on the same level not only belong to the upper layer or they have an effect on the factors in the upper layer, but also dominate the factors of the next layer or they are affected by the next layer.

To conduct the judgment matrix: The 1~9 scale table (Table 2) is introduced in this study. The author combines the method of questionnaires survey and the

Table 1: Evaluation indicator system of the experimental teaching

First-level indicators	NO	Weight	Second-level indicators	NO
Teaching management of experiment	U_1	w_1	Teaching plan schedule of experiment	u_{11}
			Teaching syllabus of experiment	u_{12}
			Teaching materials or instructions of experiment.	u_{13}
			Lesson plans of experiment	u_{14}
			Work records of experiment	u_{15}
Teaching process of experiment	U_2	w_2	Number of students being guided	u_{21}
			Teaching of experiment contents	u_{22}
			Method of experimental teaching	u_{23}
			Guiding of experimental teaching	u_{24}
Teaching effect of experiment	U_3	w_3	Development of experiment operation skills	u_{31}
			Results of experiment tests	u_{32}
			Qualified rate of the experiment report	u_{33}
			Independent completion rate of experiment report	u_{34}
			Evaluation of the students	u_{35}

Table 2: Number of judgment scales measuring the relative importance degree between the elements

Judgment scale	Definition
1	Compared with two elements, they have same importance
3	Compared with two elements, the former is more important than the latter slightly
5	Compared with two elements, the former is more important than the latter obviously
7	Compared with two elements, the former is much more important than the latter
9	Compared with two elements, the former is much more important than the latter extremely
2,4,6,8	Between the middle of two adjacent judgment scale

Table 3: Indicator of average random consistency

n	2	3	4	5	6	7	8
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41

method of expert's team and any factors are compared with each other to determine the relative importance. And then the judgment matrix U will be constructed:

$$U = \begin{pmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_n} \\ \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_n} \end{pmatrix}$$

That is:

$$U = \begin{pmatrix} u_{11} & \cdots & u_{1n} \\ \vdots & \ddots & \vdots \\ u_{n1} & \cdots & u_{nn} \end{pmatrix} \quad (1)$$

Where:

$$u_{ij} > 0; u_{ij} = \frac{1}{u_{ji}} (i \neq j); u_{ii} = 1 (i, j = 1, 2, 3 \cdots\cdots n)$$

To perform hierarchical single strong: To calculate the feature vector of every judgment matrix and their maximum eigenvalue λ_{max}, then the order in single level can be obtained:

- To calculate the total sum of the judgment matrix U by row:

$$x_i = \sum_{j=1}^{n} u_{ij} \quad (2)$$

Where:
x_i: The total sum of the row i:

- To normalize the feature vector:

$$Y = [y_1, y_2, \cdots\cdots y_n]^T \quad (3)$$

Where:

$$y_i = \frac{x_i}{\sum_{i=1}^{n} x_{ij}}$$

- To obtain maximum eigenvalue of the judgment matrix:

$$\lambda_{max} = \frac{1}{n} \sum_{i} \left(\frac{(UY)_i}{y_i} \right) \quad (4)$$

Where:
$(UY)_i$ = The element of the vector UY and its NO is I
λ_{max} = The maximum eigenvalue of the judgment matrix

To check the consistency of the judgment matrix: The main steps of checking the consistency are as follows (Xiong and Liu, 2013):

- To calculate the indicator CI used to judge the consistency of judgment matrix deviation, whose calculation equation is as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

Where:
λ_{max} = The maximum eigenvalue
n = The rank of judgment matrix

- To select the indicator RI which indicates the average random consistency of different rank judgment matrix and its values can be selected from Table 3
- To calculate the indicator CR which indicates the random consistence rate, whose calculation equation is:

$$CR = \frac{CI}{RI} \quad (6)$$

If CR is less than 0.1, the results of hierarchical sorting can satisfy the requirement for consistency, otherwise the judgment matrix will need to be revised.

To establish the evaluation set V: The evaluation set is a set which includes all possible outcomes of evaluation indicators and can be obtained by the experts. Because the evaluation set is a collection including all the evaluation results, it is only one and can be expressed as the following the equation:

$$V = \{v_1, v_2, \ldots, v_m\} \quad (7)$$

To establish evaluation membership matrix:

$$T=\begin{pmatrix}T_1\\T_2\\\vdots\\T_m\end{pmatrix}=\begin{pmatrix}t_{11} & t_{12} & \cdots & t_{1n}\\t_{21} & t_{22} & \cdots & t_{2n}\\\vdots & \vdots & \vdots & \vdots\\t_{m1} & t_{m2} & \cdots & t_{mn}\end{pmatrix} \quad (8)$$

Where:

T_i = The evaluation results of the factor of NO

t_{ij} = The membership degree of that the evaluation factor of No. i responds to the evaluation grade of No. j, which reflects the relation between fuzzy evaluation factors and evaluation grade with membership representation

n = Number of evaluation grades in the evaluation set

m = Number of the evaluated factors

To make the fuzzy comprehensive evaluation:

- To make the first-level fuzzy comprehensive evaluation

According to the index weight w which can be calculated by a fuzzy consistent matrix and established evaluation membership matrix T, the fuzzy algorithm is used for comprehensive operations. And after normalization processing is done, membership vector B of the factor U responding to the evaluation set V can be obtained (Xiong *et al*., 2013):

$$B_i=w_i*T_i=(w_{i1},w_{i2},\ldots,w_{ij})*\begin{pmatrix}t_{11} & t_{12} & \cdots & t_{1n}\\t_{21} & t_{22} & \cdots & t_{2n}\\\vdots & \vdots & \vdots & \vdots\\t_{m1} & t_{m2} & \cdots & t_{mn}\end{pmatrix} \quad (9)$$

Where:

w_i = Internal weight of the first-level evaluation index U_i (i = 1,2,3)

T_i = The membership matrix corresponding to the first-grade evaluation index U_i (i = 1,2,3)

* = The operation symbol of the fuzzy synthesis:

- To make the second-level fuzzy comprehensive evaluation

The second-level fuzzy comprehensive evaluation can be calculated by the following equation:

$$A=W*B \quad (10)$$

Where:

W = The weights among the first-level U_i (i = 1,2,3)

B = The membership vector of the factor U corresponding to the evaluation set V

* = The operation symbol of the fuzzy synthesis

A = The total evaluation vector

To determine the grade of comprehensive evaluation: In order to facilitate comparison, the comprehensive evaluation results should be converted to score and the final evaluation score is represented with the symbol E, which can be calculated by the equation:

$$E=A*V^T \quad (11)$$

Where:

A = The total evaluation vector

V^T = Transposed matrix of rating scores matrix V

* = The operation symbols of the fuzzy synthesis

CALCULATION AND ANALYSIS OF SPECIFIC DATA

Experimental simulation of AHP: Combined with the undergraduate teaching conformity assessment standards of the Ministry of Education of China and the scoring standards of teaching evaluation in the college in recent years, the structure model of AHP can be constructed to make the experimental simulation based on the above the principle and method. And then the corresponding judgment matrixes can be established and calculated.

According to the judgment matrix in Table 4, Eq. 5 and 6, the programs can be written and operated in the software of MATLAB 7.0. Then the corresponding weights can be obtained, their results of operation have been listed the last column from the Table 4 to 7, the related calculation process is as follows:

- The calculation of the judgment matrix U (Table 4)
- The calculation of the judgment matrix U_1 (Table 5)
- The calculation of the judgment matrix U_2 (Table 6)
- The calculation of the judgment matrix U_3 (Table 7)

To construct a priority judgment matrix V: According to the purpose of teaching evaluation quality, the author constructs an evaluation set including 5 levels:

$$V=(v_1,v_2,v_3,v_4,v_5)=(\text{excellent},\text{good},\text{medium},\text{passing},\text{failing})$$

To construct the evaluation membership matrix T: By means of issuing questionnaires, participants complete questionnaires to take the above five-level

Table 4: Judgment matrix U and its interior weights w_0

Level	u_1	u_2	u_3	w_0
u_1	1	4	1/3	0.2797
u_2	1/4	1	1/5	0.0936
u_3	3	5	1	0.6267

λ_{max}: 3.0858, CI: 0.0429, CR: 0.0739<0.10

Table 5: Judgment matrix U_1 and its interior weights w_1

U_1	u_{11}	u_{12}	u_{13}	u_{14}	u_{15}	w_1
u_{11}	1	1/6	1/3	4	5	0.1348
u_{12}	6	1	3	5	8	0.4991
u_{13}	3	1/3	1	6	7	0.2690
u_{14}	1/4	1/5	1/6	1	3	0.0634
u_{15}	1/5	1/8	1/7	1/3	1	0.0337

λ_{max}: 5.4131, CI: 0.1033, CR: 0.0922<0.10

Table 6: Judgment matrix U_2 and its interior weights w_2

U_2	u_{21}	u_{22}	u_{23}	u_{24}	w_2
u_{21}	1	1/6	1/4	1/5	0.0551
u_{22}	6	1	5	3	0.5509
u_{23}	4	1/5	1	1/3	0.1301
u_{24}	5	1/3	3	1	0.2639

λ_{max}: 4.2171, CI = 0.0724, CR: 0.0804<0.10

Table 7: Judgment matrix U_3 and its interior weights w_3

U_3	u_{31}	u_{32}	u_{33}	u_{34}	u_{35}	w_3
u_{31}	1	5	6	4	3	0.4745
u_{32}	1/5	1	4	2	1/3	0.1263
u_{33}	1/6	1/4	1	1/3	1/5	0.0448
u_{34}	1/4	1/2	3	1	1/3	0.0930
u_{35}	1/3	3	5	4	1	0.2614

λ_{max}: 5.3334, CI: 0.0834, CR: 0.0744<0.10

evaluation rating on the quality of practice teaching in accordance with the second-index evaluation score and on the basis of assessment membership grade can be established. According to Eq. (8), the evaluation membership matrix T_i (i = 1,2,3) can be constructed which is shown as follows:

$$T_1=\begin{pmatrix}0.18 & 0.22 & 0.45 & 0.15 & 0.00\\ 0.35 & 0.25 & 0.20 & 0.15 & 0.05\\ 0.22 & 0.25 & 0.35 & 0.12 & 0.06\\ 0.45 & 0.25 & 0.16 & 0.10 & 0.04\\ 0.40 & 0.32 & 0.20 & 0.08 & 0.00\end{pmatrix}\quad T_2=\begin{pmatrix}0.33 & 0.22 & 0.30 & 0.10 & 0.05\\ 0.52 & 0.28 & 0.15 & 0.05 & 0.00\\ 0.35 & 0.28 & 0.32 & 0.05 & 0.00\\ 0.55 & 0.35 & 0.07 & 0.03 & 0.00\end{pmatrix}$$

$$T_3=\begin{pmatrix}0.42 & 0.28 & 0.18 & 0.12 & 0.00\\ 0.45 & 0.28 & 0.15 & 0.08 & 0.04\\ 0.25 & 0.32 & 0.25 & 0.10 & 0.08\\ 0.18 & 0.25 & 0.32 & 0.15 & 0.10\\ 0.32 & 0.35 & 0.20 & 0.10 & 0.03\end{pmatrix}$$

To make the fuzzy comprehensive evaluation:

- To make first-level fuzzy comprehensive evaluation

According to the Eq. 9, the membership matrix B_i (i = 1,2,3) can be calculated, in which the fact U_i is responding to the evaluation set V:

$$B_1 = w_1 * T_1 = (0.3001, 0.2483, 0.2715, 0.1364, 0.0436)$$

$$B_2 = w_2 * T_2 = (0.4953, 0.2952, 0.1593, 0.0475, 0.0028)$$

$$B_3 = w_3 * T_3 = (0.3677, 0.2973, 0.1976, 0.1116, 0.0258)$$

- To make second-level fuzzy comprehensive evaluation

$$B=\begin{pmatrix}B_1\\ B_2\\ B_3\end{pmatrix}=\begin{pmatrix}0.3001 & 0.2483 & 0.2715 & 0.1364 & 0.0436\\ 0.4593 & 0.2952 & 0.1593 & 0.0475 & 0.0028\\ 0.3677 & 0.2973 & 0.1976 & 0.1116 & 0.0258\end{pmatrix}$$

According to Table 4, w_0 = (0.2797, 0.0936, 0.6267); According to the Eq. 10:

$$A = w_0 * B = (0.3607, 0.2834, 0.2147, 0.1125, 0.0286)$$

To determine the grade of evaluation and take the analysis of results: The quantification of evaluation grade is a comprehensive evaluation value. And it can be calculated by the weighted algebraic sum, in which the weight is membership degree. The method of the weighted algebraic sum is superior to the principle of maximum

membership degree, because it does not discard any membership in other classes at all and fully absorbs comprehensive information through a series of calculation operation.

The median score of evaluation grade can be taken as a representative from each grade and the specific points of 5 levels are as follows:

$$V = (v_1, v_2, v_3, v_4, v_5) = (\text{excellent, good, medium, passing, failing}) = (95, 85, 75, 65, 30)$$

According to the Eq. 11, the score of evaluation results of every second-level index respectively can be calculated as the following the expression of E_i (i = 1,2,3):

$$E_1 = B_1 * V^T = (0.3001, 0.2483, 0.2715, 0.1364, 0.0436) * (95,85,75,65,30)^T = 80.1585$$

$$E_2 = B_2 * V^T = (0.4953, 0.2952, 0.1593, 0.0475, 0.0028) * (95,85,75,65,30)^T = 87.2595$$

$$E_3 = B_3 * V^T = (0.3677, 0.2973, 0.1976, 0.1116, 0.0258) * (95,85,75,65,30)^T = 83.0511$$

So, the score of evaluation results of the first-level is calculated as the following:

$$E = A * V^T = (0.3607, 0.2834, 0.2147, 0.1125, 0.0286) * (95,85,75,65,30)^T = 82.6338$$

Then, the above scores are compared with the specific points of 5 levels and a conclusion will be drawn that evaluation grade in the teaching management, teaching process, teaching effect of experiment all belongs to “good” rating, finally the general result of evaluation grade belongs to "good" rating.

SOME COUNTERMEASURES AND SUGGESTIONS

To make efforts to increase the talent introduction and training: The colleges become to realize that the experiment teachers play an important role to bring up the manipulative ability, so, they are actively developing, introducing talents to enrich the team of experiment teachers.

To formulate the relevant incentive system: The college should formulate the relevant policies to encourage professional teachers to lead students to participate in relevant subject competition and experimental skills contest, so as to improve the students' ability of experiment operation skill and innovation practice.

To strengthen the construction of information network platform and reform the teaching mode of interaction: Compared with the traditional experimental teaching mode, the experiment environment which has been established based on the information network platform will promote the reform of experimental teaching mode. It can convert the past experiment model which mainly belongs to the mode of verification experiment into the comprehensive design experiment mode in which the students are the main body and the latter can mobilize the enthusiasm and initiative of the students.

To establish and improve the multi-party evaluation systems: Evaluation of experimental teaching need multi-party participation and educational administration, teachers students all may participate in the evaluation. They may be treated not only as the subject of evaluation, but also as the evaluation object. The comprehensive multilateral evaluation should be taken and the evaluation system can make a convenient evaluation to experimental teaching via the information network platform.

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