Research on Teaching Quality Based On Principal Component Analysis

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Abstract — In this paper we use principal component analysis to get factors affecting the quality of English teaching, and then construct comprehensive evaluation system. On this basis, we use fuzzy theory to evaluate the data by three-level indicator. Finally we use normalization method to get the result, which provides the scientific theory for English teaching quality and improves the quality of teaching in English.

Keywords - Principal Component Analysis; Teaching Quality; Fuzzy Comprehensive Evaluation

I. INTRODUCTION

English teaching is an important part of Chinese universities. But now there are problems in English teaching, for example, English teaching time is long but the effect is poor, lots of students have good exam results but they have low ability to use English and so on. So, college English teaching work must conform to the demands of society and the development of the times, and improve English teaching effectiveness and efficiency.

In order to improve the quality of English teaching, strengthen teaching management and further mobilize the enthusiasm of English teachers, we need quantitative method to evaluate English teaching. In order to fully assess teaching, this paper chooses appropriate English teaching indicators. Because lots of indicator may cause complex operation and information overlapping. So this paper chooses a small amount of non-relevant indicators to replace lots of related indicators. At the same time the small amount non-relevant indicators can reflect the original index information. In the current, evaluation of teaching ability of English teacher is ultimate assessment (only use students’ score to evaluate teacher). How to analyze students’ final grades can objectively reflect the teacher’s teaching? This paper considers absolute indicator and relative indicator which can reflect English proficiency of students. Next we use principal component analysis to analyze these selected indicators and then get comprehensive evaluation value of teacher education. In addition to considering the student’s final grade, it will also take into account other data. So, by questionnaire the paper gets some indicators divided into main and sub factors. Because these indicators contain ambiguity, so the quantitative analysis is not easy. Then the paper constructs multi-level fuzzy comprehensive evaluation model.

II. THE COMPREHENSIVE EVALUATION INDEX SYSTEM

A. Principle Introduction

Principal component analysis as a method of statistical analysis converts original indicators into several comprehensive indicators. Its main function is to reduce dimension. Assume there are n geographic samples, each sample has p variable descriptions. Then we get n × p geographic data matrix:

\[ X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} \]

How to find out the internal regularity of geographic thing from lots of variable data? The answer is that we solve this problem in p -dimensional space, but this kind of practice is very trouble. So we must reduce the dimension, that is using a few comprehensive indicators to replace original many indicators. However how to obtain these comprehensive indicators? The simplest solution is to use linear combination of the original indicators.

Let \( x_1, x_2, \cdots, x_p \) be the original variable indicators, \( x_1, x_2, \cdots, z_m (m \leq p) \) are their comprehensive indicators (i.e. new variable indicators), then

\[
\begin{align*}
\tilde{x}_1 &= \sum_{i=1}^{p} l_{1i} x_i \\
\tilde{x}_2 &= \sum_{i=1}^{p} l_{2i} x_i \\
&\vdots \\
\tilde{x}_m &= \sum_{i=1}^{p} l_{mi} x_i \\
\end{align*}
\]

\( \tilde{x}_i \) is linear combination of \( x_1, x_2, \cdots, x_p \) satisfying biggest variance; \( \tilde{z}_2 \) is linear combination of \( x_1, x_2, \cdots, x_p \)
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satisfying biggest variance and unrelated with \( z_1 \); \( z_m \) is linear combination of \( x_1, x_2, \ldots, x_p \) satisfying biggest variance and unrelated with \( z_1, z_2, \ldots, z_{m-1} \).

The new indicator \( z_i (i = 1, 2, \ldots, m) \) is the i-principal component of original indicator \( x_j (j = 1, 2, \ldots, p) \). The largest percentage in total variance is \( z_1 \), and then variance of \( z_2, z_3, \ldots, z_m \) are successive reduction. We often choose a few in the front of the maximum principal components. The aim is to reduce the index, but also made clear the main contradiction, simplify the relationship between indicators.

Based on the above analysis, to obtain the principal component is that we determine the load \( l_j (i = 1, 2, \ldots, m; j = 1, 2, \ldots, p) \) of original indicator \( x_j (j = 1, 2, \ldots, p) \) in the principal component \( z_i (i = 1, 2, \ldots, m) \). They are eigenvectors corresponding to \( m \) larger eigenvalues of correlation matrix of \( x_1, x_2, \ldots, x_p \), respectively.

B. System Construction

We put all individual data in the original data into the above every linear combination formula of the principal component, and then get principal component score values of all main bodies. The absolute indicator related with students’ all main bodies. The relative indicator is the progress rate \( \gamma = \frac{\sum E_j}{N_j} \).

The relative indicator is the progress rate

\[
x_j = (0.666667, 0.45454545, 0.675676, 0.774194)
\]

pass rate \( x_2 = (0.93055555, 0.90909090, 0.93243243, 0.983870968) \)

excellent rate \( x_3 = (0.152777778, 0.227272727, 0.135510511, 0.24935484) \)

average score \( x_4 = (74.59772222, 76.25, 73.32432432, 76.67741935) \)

standard deviation \( x_5 = (5.103583218, 8.705975, 6.480966119, 5.139267531) \)

First, we calculate \( x_q \), and then get the original data matrix \( X \):

\[
X = \begin{bmatrix}
x_1 \\
x_2 \\
x_3 \\
x_4 \\
x_5 
\end{bmatrix}
\]

Second, we remove the dimensional interference between indicators. By the standardized treatment, we get standardized matrix \( Z \) where \( Z_q = \frac{x_q - \bar{x}}{s} \). Further we construct the characteristic equation of relative matrix \( v \) of \( x_j \) and \( x_q \), then get the characteristic root \( (\lambda_1, \lambda_2, \ldots, \lambda_p) \).

Through \( q_i = \frac{\lambda_i}{\sum_{i=1}^p \lambda_i} \), we get the contribution rate \( q_i \).

<table>
<thead>
<tr>
<th>Composition analysis</th>
<th>characteristic root ( \lambda_i )</th>
<th>contribution rate ( q_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( (x_1)_1 )</td>
<td>2.36259</td>
<td>0.47252</td>
</tr>
<tr>
<td>( (x_2)_2 )</td>
<td>1.35642</td>
<td>0.27128</td>
</tr>
<tr>
<td>( (x_3)_3 )</td>
<td>1.281</td>
<td>0.2562</td>
</tr>
<tr>
<td>( (x_4)_4 )</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>( (x_5)_5 )</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Next, by Jacobi iteration method of orthogonal transformation, we get the corresponding eigenvectors matrix

\[
\begin{bmatrix}
0.29714 & 0.47187 & -0.43607 & -0.64782 & 0.28146 \\
-0.41695 & 0.63211 & 0.065738 & -0.056332 & -0.64738 \\
0.73834 & -0.16843 & -0.083372 & -0.0092981 & -0.64765 \\
0.25441 & 0.47054 & -0.31683 & 0.75816 & 0.1975 \\
0.35776 & 0.35776 & 0.35776 & -0.047567 & 0.20791 
\end{bmatrix}
\]

Finally, by Matlab we get the score matrix

DOI 10.5013/IJSSST.a.17.21.16 16.2 ISSN: 1473-804x online, 1473-8031 print
We can calculate \(E(A) = -3.4219\), \(E(B) = 1.1335\), \(E(C) = 2.0796\) and \(E(D) = -1.5184\) from score matrix. So A class is the worst, next is D class, next is B class and C class is the best.

### III. MULTI-LEVEL FUZZY COMPREHENSIVE EVALUATION MODEL

#### A. Theory Introduction

Assume \(k\) layer compose factor domain \(U (k \geq 2)\), \(U = (U_1, U_2, \ldots, U_k)\) is \(m\)-th factor of the first layer (the highest layer), \(V = (v_1, v_2, \ldots, v_n)\) is its review set, so the multi-level fuzzy comprehensive evaluation model is \(B = A \circ R\) where \(A\) is each layer’s weight vector, \(x\) is every weight vector of the \(x+1\) layer, \(R\) is the lowest layer (the \(k\) layer) fuzzy relation matrix.

Multi-level fuzzy comprehensive evaluation method is that we calculate from the lowest layer (the \(k\) layer) upward step by step until to get the last set of review \(B\). The evaluation conclusion of the \(k\) layer is membership of the \(k-1\) layer factor. Calculation steps are

1. (1) calculate the fourth layer and get
   \[
   B_{11} = A_{11} \circ R_{11} \\
   B_{12} = A_{12} \circ R_{12} \\
   \vdots \\
   B_{1r} = A_{1r} \circ R_{1r} \\
   \vdots \\
   B_{mq} = A_{mq} \circ R_{mq} \\
   \]  
   When finishing the calculation of the third layer, let \(R_i = \begin{pmatrix} B_{i1} \\
B_{i2} \\
\vdots \\
B_{ip} \\
\end{pmatrix}, R_m = \begin{pmatrix} B_{m1} \\
B_{m2} \\
\vdots \\
B_{mp} \\
\end{pmatrix}\).

2. (2) calculate the second layer and get
   \[
   B_1 = A_1 \circ R_1 \\
   \vdots \\
   B_m = A_m \circ R_m \\
   \]

(3) calculate the highest layer and get the last set of review \(B = A \circ R\), then perform quantitative processing.

#### B. Model Establishment

Now commonly used way of evaluation is the ultimate evaluation, that is using score to evaluate English teacher. So under this method how to analyze the student’s final grade can objectively reflect the teacher’s teaching? In this paper, we consider absolute indicator and relative indicator which can reflect students’ English level. Next we use principal component analysis to analyze these selected indicators and then get comprehensive evaluation value of teacher education. In addition to considering the student’s final grade, it will also take into account other data. So, by questionnaire the paper gets some indicators divided into main and sub factors. Because these indicators contain ambiguity, so the quantitative analysis is not easy. Then the paper constructs multi-level fuzzy comprehensive evaluation model.

First, build on questionnaire about English teachers’ teaching quality and level, and then investigate the access, finally get the following data:

<table>
<thead>
<tr>
<th>First layer</th>
<th>Second layer (main factor)</th>
<th>Third layer (sub factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching attitude (F_1(0.2))</td>
<td>The degree of class preparation (F_{11}(0.3))</td>
<td>Classroom teaching record (F_{12}(0.3))</td>
</tr>
<tr>
<td>Classroom teaching record (F_{12}(0.3))</td>
<td>Complete the requirements of teaching outline (F_{21}(0.2))</td>
<td>The combination of extracurricular materials and materials (F_{22}(0.4))</td>
</tr>
<tr>
<td>Teaching content (F_2(0.3))</td>
<td>The implementation of the class discussion (F_{23}(0.4))</td>
<td>Arouse the students’ interest in learning English (F_{31}(0.4))</td>
</tr>
<tr>
<td>Teaching strategies and methods (F_3(0.2))</td>
<td>The moderation of English teaching (F_{32}(0.3))</td>
<td>Guidance for differences (F_{33}(0.3))</td>
</tr>
<tr>
<td>Teaching effect (F_4(0.3))</td>
<td>Test scores at ordinary times (F_{41}(0.4))</td>
<td>English communication and application ability (F_{42}(0.4))</td>
</tr>
<tr>
<td>Class attendance and homework (F_{43}(0.2))</td>
<td></td>
<td>Class attendance and homework (F_{43}(0.2))</td>
</tr>
</tbody>
</table>
TABLE III THE NUMBER OF STUDENTS AND CLASS TEACHER

<table>
<thead>
<tr>
<th>Main factor</th>
<th>Sub factor</th>
<th>Student evaluation (200)</th>
<th>class teacher evaluation (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>better</td>
<td>good</td>
</tr>
<tr>
<td>Teaching attitude F1 (0.2)</td>
<td>F11(0.3)</td>
<td>46</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>F12(0.3)</td>
<td>42</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>F13(0.4)</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Teaching content F2 (0.3)</td>
<td>F21(0.2)</td>
<td>34</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>F22(0.4)</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>F23(0.4)</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Teaching strategies and methods F3 (0.2)</td>
<td>F31(0.4)</td>
<td>48</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>F32(0.3)</td>
<td>40</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>F33(0.3)</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td>Teaching effect F4 (0.3)</td>
<td>F41(0.4)</td>
<td>50</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>F42(0.4)</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>F43(0.2)</td>
<td>46</td>
<td>26</td>
</tr>
</tbody>
</table>

Second, analyze collected objects and fuzzy evaluate the third layer indicator.

TABLE IV FUZZY EVALUATION OF INDICATOR F11 FROM 200 STUDENTS

<table>
<thead>
<tr>
<th>rank</th>
<th>better</th>
<th>good</th>
<th>general</th>
<th>poor</th>
<th>poorer</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>46</td>
<td>24</td>
<td>26</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>proportion</td>
<td>0.46</td>
<td>0.24</td>
<td>0.26</td>
<td>0.04</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The evaluation result is fuzzy set \( R_{11} \) = \( (0.46, 0.24, 0.26, 0.04, 0.00) \). Similarly, we can get the following fuzzy set of indicator F12, F13 from 200 students

\( R_{11} \) = \( (0.42, 0.20, 0.32, 0.04, 0.02) \)
\( R_{11} \) = \( (0.20, 0.18, 0.50, 0.10, 0.02) \)

So we obtain the single factor evaluation matrix of indicator F1

\[
R_{11} = \begin{bmatrix}
0.46 & 0.24 & 0.26 & 0.04 & 0.00 \\
0.42 & 0.20 & 0.32 & 0.04 & 0.02 \\
0.20 & 0.18 & 0.50 & 0.10 & 0.02
\end{bmatrix}
\]

Next analyze collected objects and fuzzy evaluate the second layer indicator. The weight distributions of three indicators of teaching attitude F1 are F11(0.3), F12(0.3), F13(0.4), so A11 = (0.3, 0.3, 0.4) is a fuzzy set. Finally the comprehensive evaluation of F1 from 200 students is

\[
B_{11}' = A_{11} \times R_{11} = \begin{bmatrix}
0.46 & 0.24 & 0.26 & 0.04 & 0.00 \\
0.42 & 0.20 & 0.32 & 0.04 & 0.02 \\
0.20 & 0.18 & 0.50 & 0.10 & 0.02 
\end{bmatrix}
\]

From 0.3440 + 0.2040 + 0.3740 + 0.0640 + 0.0140 = 1, we get

\[
B_{11}' = \left( \begin{array}{c}
0.3440 \\
0.2040 \\
0.3740 \\
0.0640 \\
0.0140
\end{array} \right)
\]

We use “normalization” to process evaluation results

\[
B_{11}'' = \frac{B_{11}'}{\sum B_{11}'} = \left( \begin{array}{c}
0.3440 \\
0.2040 \\
0.3740 \\
0.0640 \\
0.0140
\end{array} \right)
\]

From the normalization result, 34.40 percent of 200 students think that the evaluation of this teacher’s teaching attitude is “better”, 20.40 percent is “good”, 37.40 percent is “general”, 6.40 percent is “poor”, 1.40 percent is “poorer”. Similarly, we can get the comprehensive evaluation of F2, F3, F4

\[
B_{12} = (0.2008, 0.24, 0.324, 0.24, 0.004)
\]

\[
B_{13} = (0.3960, 0.2820, 0.2490, 0.0700, 0.0030)
\]

\[
B_{14} = (0.3560, 0.2520, 0.2480, 0.1240, 0.0200)
\]

Then we get
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\[ R_i = \begin{bmatrix}
0.3340 & 0.2040 & 0.3740 & 0.0640 & 0.0140 \\
0.208 & 0.24 & 0.324 & 0.224 & 0.004 \\
0.3960 & 0.2820 & 0.2490 & 0.0700 & 0.0030 \\
0.3560 & 0.2520 & 0.2480 & 0.1240 & 0.0200
\end{bmatrix} \]

So

\[ B_1 = A_1 \odot R_1 = (0.2 \ 0.3 \ 0.2 \ 0.3) \times \begin{bmatrix}
0.3340 & 0.2040 & 0.3740 & 0.0640 & 0.0140 \\
0.208 & 0.24 & 0.324 & 0.224 & 0.004 \\
0.3960 & 0.2820 & 0.2490 & 0.0700 & 0.0030 \\
0.3560 & 0.2520 & 0.2480 & 0.1240 & 0.0200
\end{bmatrix} = (0.3172 \ 0.2448 \ 0.2962 \ 0.1312 \ 0.0106) \]

\[ B_1 \] is the teacher’s fuzzy comprehensive evaluation. It shows that 31.72 percent of 200 students think that the evaluation of teacher is “better”, 24.48 percent is “good”, 29.28 percent is “general”, 13.12 percent is “poor”, 1.06 percent is “poorer”. Similarly we get the fuzzy comprehensive evaluation result of class teacher

\[ B_2 = (0.2400 \ 0.2000 \ 0.4000 \ 0.1600 \ 0.0000) \]

Next we test the model and finally get the comprehensive evaluation value.

IV. CONCLUSION

In order to construct multi-level fuzzy comprehensive evaluation model for English teaching quality, the paper first obtain the evaluation indicator number of students and class teachers, and then get the teacher’s evaluation rank by multi-level fuzzy comprehensive evaluation. The aim is promoting English teaching and improving teacher’s teaching ability.

REFERENCES