TELKOMNIKA, Vol. 11, No. 9, September 2013, pp. 5384~5394
ISSN: 2302-4046

Comprehensive Evaluation of Examination Quality based on Fuzzy AHP

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Abstract

Examination is undoubtedly one of good means to evaluate what and how much the examinees have mastered. Effective evaluation of the quality of curriculum examination will not only contribute to scientifically testing the students' mastery of the knowledge but also help instruct the teachers to set scientific tests. This paper establishes the evaluation indexes of curriculum quality, calculates the weight of them, and gives effective evaluation of the quality of course examination by using the fuzzy AHP comprehensive evaluation, which has practical values in improving the efficiency of teaching evaluation. The research for the examination quality evaluation system is to accurately reflect and describe the rationality of examination quality index system so as to improve the rationalization level of examination papers.

Keywords: *quality of curriculum examination, evaluation index system, fuzzy AHP comprehensive evaluation*

1. Introduction

In China's universities, teachers usually compose test papers by themselves or drawing from test database. After the exam, the students' achievements are simply summarized, and the scores are compared. Some departments do some analyses about the difficulty and contrast of the examination papers, but they can not form a system. The major work in the project (examination) is laid on the preceding management, while the "closed loop" project control is ignored. In order to solve this problem, a reasonable test quality evaluation system needs to be established [1]. The aim of studying on the evaluation of examination quality system is to accurately reflect and describe the rationality of examination quality index system, and improve the rationalization degree of examination paper.

In the nineteen fifties, American Psychological Association formulated the "educational and psychological testing standards", which triggered a series of test specification. They became the core of quality standards of academic examination, and provided specifications for large-scale standardized tests. And the Educational Testing Service of the United States also developed standards for quality and fairness. Joint Committee on Test Practices had organized and developed Code of Fair Testing Practices in Education. All of these created a precedent for the evaluation of examination quality. In China, with the deepening of education reform, a new upsurge in education measurement and evaluation is in the making. Academic research and academic exchanges in this field are increasingly active. Applying analytic hierarchy process (AHP), Wanyou Deng puts forward the idea of comprehensive examination paper evaluation system, and by using asp.net technology Shezheng Xu designs network examination paper evaluation system. Yan Yu and Wensheng Huang put forward the construction and improvement of College Teachers' classroom teaching quality evaluation system based on fuzzy comprehensive evaluation [2]. The above index systems still have some defects, and the designers haven't given scientific proof to their systems by using appropriate evaluation method, and they need further improvement.

Using hierarchical fuzzy comprehensive evaluation method, this paper applied qualitative analysis combined with quantitative analysis method, and gave effective evaluation

Received January 15, 2013; Revised June 14, 2013; Accepted June 24, 2013

of examination quality. Analytic hierarchy process (AHP) has its own unique advantage for every index layer assignment, and fuzzy mathematical evaluation method has great advantage in post-processing fuzzy problem, therefore, the two kinds of methods can be combined, to make the evaluation model systematic and procedural, so that the test quality evaluation is easier to operate. It has good application value in the evaluation of examination quality, and is a more practical method.

2. Determination of Evaluation Index of Course Examination

According to the characteristics of college examination, evaluation index system framework of curriculum examination quality can be divided into three layers. Target layer: completion of curriculum examination quality─highly summarize and evaluate the quality of curriculum examination. Criterion layer: to describe from 4 aspects the result of test, the quality of test questions, the quality of test paper and the structure of test paper [3, 4]. Index layer: to be divided into 9 quantitative indexes and 2 qualitative indexes. See Table 1. The evaluation of attribute index is the specific content and scope of the evaluation target, the attribute index according to the target layer.

Table 1. Evaluation Index System of Examination Quality

Target layer A	Criterion layer B	Index layer C
quality of course examination	B_1 result of test	C_{11} excellence rate
		C_{12} failure rate
		C_{13} standard deviation
	B_2 quality of test question	C_{21} skewness
		C_{22} kurtosis
		C_{23} difficulty
	B_3 quality of test paper	C_{31} reliability
		C_{32} validity
		C_{33} partition degree
	B_4 structure of test paper	C_{41} content coverage
		C_{42} structure and quantity

3. Determination of Criteria of Evaluation Index of Examination Quality

3.1. Classification of Criteria of Evaluation Index

In order to obtain an intuitive evaluation of examination quality and give a more understandable judgment on the result of the test, the specific targeted value should be changed into evaluation value to determine the quality of the course test. According to some evaluation indexes and research experience, this paper divides the indexes into four classes, namely excellent, good, general and poor.

3.2. Determination of Standard Index

The selection and correct and reasonable determination of standard index have direct influence on the result of the test in quality evaluation index system. In order to ensure the standard index to be scientific and reliable, the qualitative index of this paper is based on judgment and determination of some universities. And the quantitative index is in accordance with classical test theory and the general standard both at home and abroad [5, 6].

3.2.1. Basis of Determining the Grade Standard of Quantitative Evaluation

(1) Excellent rate of C_{11} and failure rate of C_{12} are calculated according to the conventional calculation method.

(2) Evaluation standards of standard deviation of C_{13}, skewness of C_{21}, kurtosis of C_{22}, difficulty of C_{23}, reliability of C_{31}, validity of C_{32} and partition degree of C_{33} are based on literature.

3.2.2. Description of Grade Standard of Qualitative Evaluation

Evaluation standards of coverage in C_{41} and structure and quantity in C_{42} are set up by combining the evaluation criteria of some educational administration departments and the advice of some experts.

Table 2. Qualitative Evaluation Index of Course Examination Quality

Index	Standard			
	excellent	good	general	poor
C_{41}	universal coverage	broad coverage	general coverage	lots of missing
C_{42}	beasonable structure, comprehensive question, reasonable design of score	reasonable structure, moderate question, reasonable design of score	reasonable structure, basic types of question, general design of score	general structure, unitary question, unreasonable design of score

4. Fuzzy AHP Comprehensive Evaluation of Course Examination Quality

Due to the complex index formula in index system involved in C_{13}(standard deviation), C_{21}(skewness), C_{22}(kurtosis), C_{23}(difficulty), C_{31}(reliability), C_{32}(validity) and C_{33}(partition degree), this paper specially construct the WEB model and design the assessment system of examination quality to make the above quantitative index output directly through the software for the purpose of easily understanding.

4.1. WEB Model of Examination Quality Evaluation

Through the use of PHP and MySQL dynamic techniques which are used in web site design and integrated development platform, that is Linux + Apache + PHP +MySQL +Dreamweaver, the researchers establish a convenient, practical course examination quality assessment system.

4.1.1. Design of System Module and Need Analysis

Based on the management system of teaching quality, evaluation system of course examination quality can be divided into several functional modules, including input information, structure of test paper, input the score, paper analysis, statistical query, data sorting and system setting. Each module can not only be used independently, but also interact to constitute constitute a unified whole [7].

(1) Diagram of system structure

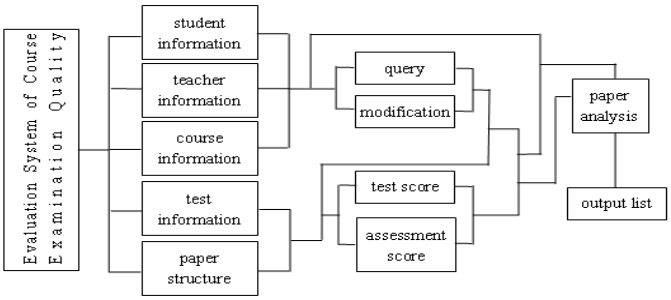

Figure 1. Diagram of System Structure

(2) Function of module

(a) Input information: batch input information of students and teachers can be accomplished.

(b) Structure of test paper: the input, preservation, modification and query of the structure of test paper for analysis (such as blank-filling, multiple choice and other kinds of questions) can be accomplished.

(c) Input the score: input of total score, subtest score, simple question score and regular score can be accomplished by using some set of test paper.

(d) Paper analysis: through retrieving the database and analyzing of standard deviation, difficulty, reliability, validity, kurtosis of a certain set of paper, a conclusion can be drawn. Also some specific questions can be statistically analyzed.

(e) Statistical query: the query of student information, teacher information, test paper information and performance information can be realized. And it also supports complex query and fuzzy query.

(f) Data sorting: due to the huge amount of data in the system, some of the data can be optimized or deleted to reduce the pressure on the server.

(g) System setting: this system is a multi-user system, which can assign permissions to different user.

(3) Work flow chart

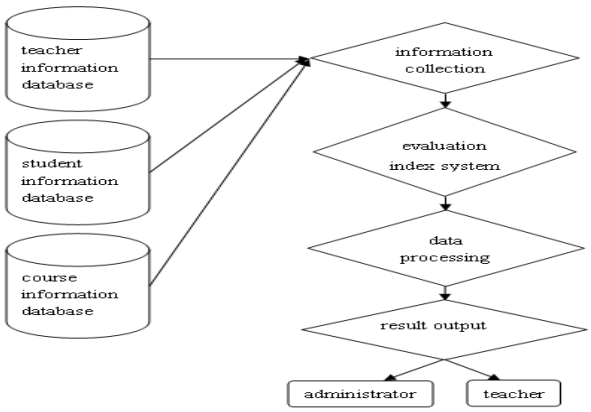

Figure 2. Work Flow Chart

(4) Database structure

The database Kechengzhiliangfenxi is established by using PhpMyAdmin (graphical database management software), which consists of score table (chengji), department table (dept), teacher information table (jiaoshi), course information table (kecheng), regular score (pingshichengji), final exam score (qimokaohe), authority allocation table (role), structure of test table (shijuanjiegou), test index table(shijuansuoyin), user(user), simple questions score table (xiaotidefen), student information table (xuesheng), total score (zongpingchengji) and other tables. The score table is the core of the database, as shown in Chart 3.

	Field	Type	Attributes	Null	Default	Extra	Action
☐	Id	int(11)		No		auto_increment	
☐	xuehao	varchar(20)		Yes	*NULL*		
☐	xingming	varchar(20)		Yes	*NULL*		
☐	shijuanbianhao	varchar(20)		Yes	*NULL*		
☐	jiegoumingcheng	varchar(40)		Yes	*NULL*		
☐	jiegoufenshu	float		No	0		
☐	defen	float		No	0		
☐	jiebie	varchar(20)		Yes	*NULL*		
☐	xibie	varchar(40)		Yes	*NULL*		
☐	zhuanye	varchar(40)		Yes	*NULL*		
☐	banji	varchar(20)		Yes	*NULL*		

Figure 3. Database Structure

4.1.2. System Implementation

This system mainly uses PHP language to program. Because it is not the focus of the research, this paper only describes key codes of some quantitative index program in evaluation index system.

(1) Programming standard deviation

```
……
$sql1="select sum(qimochengji)/count(*) from chengji where shijuanbianhao like '$shijuanbianhao' and xibie like '$xibie'";
$query1 = $DB->query($sql1);
$result=$DB->fetch_array($query1);
$ave=round($result[1],3);
// the above is the average algorithm

$biaozhuncha=0;
$sql = "select * from chengji where shijuanbianhao = '$shijuanbianhao'";
$query = $DB->query($sql);
while($result=$DB>fetch_array($query)){
$qimochengji=$result['qimochengji'];
$biaozhuncha=$biaozhuncha+($qimochengji-$ave)*($qimochengji-$ave);
$biaozhuncha=sqrt($biaozhuncha/($zongshu-1));
……
```

(2) Programming of kurtosis index

```
……
$sql 1= "select count(*) as zongshu from chengji where shijuanbianhao like '$shijuanbianhao' and xibie like '$xibie'";
$query1 = $DB->query($sql1);
$result=$DB->fetch_array($query1);
$zongshu=$result['zongshu'];
$fengdu=0;
$sql = "select * from chengji where shijuanbianhao = '$shijuanbianhao' and xibie like '$xibie'";
$query = $DB->query($sql);
while($result=$DB->fetch_array($query)){
$fengdu=$fengdu+(($qimochengji-$ave)/$biaozhuncha)*(($qimochengji-$ave)/$biaozhuncha)*(($qimochengji-$ave)/$biaozhuncha)*(($qimochengji-$ave)/$biaozhuncha);
$fengdu=($fengdu/$zongshu-3)*sqrt($zongshu/24);
```

(3) Programming of skewness index

```
……
$piandu=0;
$sql = "select * from chengji where shijuanbianhao = '$shijuanbianhao' and xibie like '$xibie'";
$query = $DB->query($sql);
while($result=$DB->fetch_array($query)){
$shijuanchengji=$result['shijuanchengji'];
$piandu=$piandu+($shijuanchengji-$ave)/$biaozhuncha;
$piandu=$piandu*sqrt(1/(6*$zongshu));
……
```

(4) Programming of reliability index

```
……
$xindu=0;
$sql = "select * from chengji where shijuanbianhao = '$shijuanbianhao' and xibie like '$xibie'";
$query = $DB->query($sql);
$biaozhuncha=sqrt($biaozhuncha/($zongshu-1));
$obiaozhuncha=sqrt($obiaozhuncha/($ozongshu-1));
```

```
$jbiaozhuncha=sqrt($jbiaozhuncha/($jzong
shu-1));
$xindu=(2*$biaozhuncha/($jbiaozhuncha*$
obiaozhuncha))/(1+($biaozhuancha/($jbiaozhuncha*$obiaozhuncha)));
……
(5) ( v ) Programming of validity index
……
$xiaodu=0;
$sql="select sum(qimochengji)/count(*),sum(pingshichengji)/count(*) from qimokaohe
where shijuanbianhao like '$shijuanbianhao' and xibie like '$xibie' and zhuanye like '$zhuanye'
and banji = '$banji'";

$query = $DB->query($sql);
$result=$DB->fetch_array($query);
$ave=round($result[1],1);
$pave=round($result[2],2);
$sql1= "select * from chengji where shijuanbianhao = '$shijuanbianhao' and xibie like
'$xibie'";
$query1 = $DB->query($sql1);
while($result=$DB->fetch_array($query1)){
$qimochengji=$result['qimochengji'];
$pingshichengji=$result['pingshichengji'];
$xiaodu=$xiaodu+(($qimochengji-$ave)*($pingshichengji-$pave));}
$sql2= "select * from chengji where shijuanbianhao = '$shijuanbianhao' and xibie like
'$xibie'";
$query2 = $DB->query($sql2);
$pbiaozhuncha=sqrt($pbiaozhuncha/($zongshu-1));
$xiaodu=$xiaodu/($zongshu*$biaozhuncha*$pbiaozhuncha);
……
```

Through retrieving the data, the evaluation personnel can calculate the kurtosis, skewness, difficulty, reliability and validity, count up the number of outstanding student, and that of failures and pass, and depict the normal distribution of scores.

The researcher randomly select examination data of one class from a university, choose index value of quantitative index calculated by WEB software and fill in the table below. Qualitative index of C_{41} (content coverage) and C_{42} (structure and quantity of test paper) are described in Table 3.

Table 3. Data Sheet of a Course Test Result

Criterion layer B	Index layer C	Index property	Specific index value
B_1	C_{11}	quantitative	0.167
	C_{12}	quantitative	0.333
	C_{13}	quantitative	13.676
B_2	C_{21}	quantitative	0
	C_{22}	quantitative	-3.674
	C_{23}	quantitative	0.622
B_3	C_{31}	quantitative	0.143
	C_{32}	quantitative	0.971
	C_{33}	quantitative	0.81
B_4	C_{41}	qualitative	qualitative description in the report
	C_{42}	qualitative	qualitative description in the report

Criteria of quantitative index evaluation in evaluation index system are determined by consulting experts and comprehensively analyzing the index value of many course test index. See Table 4.

Table 4. Criteria of Quantitative Index Evaluation

Index	Criterion			
	excellent	good	general	poor
C_{11}	<0.1	0.1< C_{11} <0.2	0.2< C_{11} <0.4	>0.4
C_{12}	<0.1	0.1< C_{12} <0.2	0.2< C_{12} <0.4	>0.4
C_{13}	<10	5< C_{13} <15	0≤ C_{13} <5	>15
C_{21}	0	-0.2< C_{21} <0.2	-0.5< C_{21} <0.5	>0.5or<-0.5
C_{22}	0< C_{22} <2	2≤ C_{22} ≤5 or -2≤ C_{22} ≤-5	0	>5or<-5 or -2≤ C_{22} <2
C_{23}	0.4< C_{23} <0.7	0.3< C_{23} <0.85	0.1< C_{23} <0.9	>0.9or<0.1
C_{31}	1	0.8< C_{31} <1	0.4≤ C_{31} ≤0.8	<0.4
C_{32}	>0.8	0.4< C_{32} <0.8	0.4	<0.4
C_{33}	≥0.4	0.3< C_{33} <0.4	0.2< C_{33} <0.3	≤ 0.2

4.2. Fuzzy AHP Comprehensive Evaluation of Course Examination Quality

4.2.1. Determining the Index Weight by Means of AHP

(1) Through designing the investigation form of comparing evaluation index weight of course quality, and inviting experts to compare the evaluation elements, we adjust results of comparison, build judgment matrix of $A-B$, B_1-C, B_2-C, B_3-C, B_4-C, calculate the normalization vector corresponding to the largest eigenvalue and the maximum eigenvalue by use of mathematical tools Matlab, and have consistent check and determine the weight coefficient. The results are shown in the table below. See Table 5 to Table 9:

Table 5. $A-B$ Judgment Matrix and Results of Weight Coefficient

	B_1	B_2	B_3	B_4	Weight Coefficient
B_1	1	3	3	7	0.500
B_2	1/3	1	1	5	0.214
B_3	1/3	1	1	5	0.214
B_4	1/7	1/5	1/5	1	0.071
consistency test	λ_{max} =4.1350	CI =0.0450	RI =0.9000	CR =0.0500	

Table 6. B_1-C Judgment Matrix and Results of Weight Coefficient

	C_{11}	C_{12}	C_{13}	Weight coefficient
C_{11}	1	1	2	0.400
C_{12}	1	1	2	0.400
C_{13}	1/2	1/2	1	0.200

Table 7. B_2-C Judgment Matrix and Results of Weight Coefficient

	C_{21}	C_{22}	C_{23}	Weight coefficient
C_{21}	1	1	1	0.333
C_{22}	1	1	1	0.333
C_{23}	1	1	1	0.333

Table 8. B_3-C Judgment Matrix and Results of Weight Coefficient

	C_{31}	C_{32}	C_{33}	Weight coefficient
C_{31}	1	1	1	0.333

C_{32}	1	1	1	0.333
C_{33}	1	1	1	0.333
consistency test	$\lambda_{\max}$ =3.000	CI =0.0	RI =0.58	CR =0.0

Table 9. $B_4 - C$ Judgment Matrix and Results of Weight Coefficient

	C_{41}	C_{42}	Weight coefficient
C_{41}	1	2	0.667
C_{42}	1/2	1	0.333

(2) Through the solution of $A-B$, $B_i - C$ judgment matrix, we can calculate weight coefficient of each index in C layer for the general objective A.

Table 10. System of Course Test Quality Evaluation Index and its Weight

Weight of layer C relative to the layer B	Weight of layer C relative to the layer A	Importance order
0.400	0.200	1
0.400	0.200	1
0.200	0.100	3
0.333	0.071	4
0.333	0.071	4
0.333	0.071	4
0.333	0.071	4
0.333	0.071	4
0.333	0.071	4
0.667	0.047	10
0.333	0.024	11

4.2.2. Fuzzy Comprehensive Evaluation

(1) Obtainment of comment set of qualitative index

We invite experts to give score for course test paper, according to the qualitative evaluation criteria, the results are shown in Table 11.

Table 11. Fuzzy Comprehensive Evaluation Matrix

Criterion layer B	Index layer C	Fuzzy comprehensive evaluation matrix			
		excellent	good	general	poor
B_1	C_{11}	1	0	0	0
	C_{12}	1	0	0	0
	C_{13}	0	1	0	0
B_2	C_{21}	1	0	0	0
	C_{22}	1	0	0	0
	C_{23}	1	0	0	0
B_3	C_{31}	1	0	0	0
	C_{32}	1	0	0	0
	C_{33}	1	0	0	0
B_4	C_{41}	0.2	0.7	0.1	0
	C_{42}	0.3	0.5	0.2	0

We invite ten experts to conduct grade evaluation on the "C_{41} content coverage". The standards are divided into "excellent, good, general and poor". Two of the experts give excellent evaluation, seven of them give good evaluation, one gives general evaluation, no one gives poor evaluation. The number is respectively divided by the total number. Fuzzy evaluation matrix is obtained, they are C_{41} $[0.2\ 0.7\ 0.1\ 0]$.

Also, fuzzy evaluation matrix C_{42} is obtained, they are $[0.3\ 0.5\ 0.2\ 0]$.

(2) Obtainment of comment set of quantitative index

By using calculation method of membership and consulting evaluation standard of quantitative index in Table 4, we can get fuzzy comprehensive evaluation matrix.

For example, in order to test quantitative index reliability (C_{31}), the experts give membership function of each evaluation grade:

$$f_{11}=\begin{cases}1, & x>15\\ \dfrac{x-11}{15-11}, & 11<x\le 15\\ 0, & x\le 11\end{cases} \quad (1)$$

$$f_{12}=\begin{cases}\dfrac{15-x}{15-11}, & 11<x\le 15\\ \dfrac{x-8}{11-8}, & 8<x\le 11\\ 0, & other\end{cases} \quad (2)$$

$$f_{13}=\begin{cases}\dfrac{11-x}{11-8}, & 8<x\le 11\\ \dfrac{x-5}{8-5}, & 5<x\le 8\\ 0, & other\end{cases} \quad (3)$$

$$f_{14}=\begin{cases}\dfrac{8-x}{8-5}, & 5<x\le 8\\ 1, & 0\le x\le 5\\ 0, & other\end{cases} \quad (4)$$

So, $f_1=[1000]$

Similarly, we can draw the membership function of C_{11} (excellence rate), C_{12} (failure rate), C_{13} (standard deviation), C_{21} (skewness), C_{22} (kurtosis), C_{23} difficulty, C_{32} validity and C_{33} partition degree of its, and calculate the membership of indexv[8].

(3) The first class comprehensive evaluation

According to the formula 5 :

$$B=W*(B_1B_2\cdots B_N)^T=(w_1w_2\cdots w_N)*(B_1B_2\cdots B_N)^T \quad (5)$$

A comprehensive evaluation can be obtained[9, 10]. For layer B_1, its sub-indexes of relative weight were 0.400, 0.400, 0.200, then $W_1=[0.400\ 0.400\ 0.200]$. By consulting Table 11, we can obtain matrix R_1:

$$R_1 = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

By applying matrix multiplication, we can get: $B_1 = [1\ 0\ 0\ 0]$.

Similarly, with the calculation steps of B_1, we can get the results layer B_2, B_3 and B_4: $B_2 = [1\ 0\ 0\ 0]$, $B_3 = [1\ 0\ 0\ 0]$, $B_4 = [0.233\ 0.633\ 0.133\ 0]$.

(4) The second class comprehensive evaluation

Evaluation results of the second class are obtained by calculation. See Table 12:

$$B = W^* R = [0.500\ 0.214\ 0.214\ 0.071] * \begin{bmatrix} 0.800 & 0.200 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0.233 & 0.633 & 0.133 & 0 \end{bmatrix} = [0.8445\ 0.1449\ 0.0094\ 0] \quad (6)$$

Table 12. Results of The Second Class Comprehensive Evaluation

Case of specific numerical evaluation	Fuzzy comprehensive evaluation matrix			
	excellent	good	general	poor
	0.8445	0.1449	0.0094	0

From Table 12 we can understand the quality of evaluation index system in course test: possibility of excellent quality is 84.45%; possibility of good quality is 14.49%; possibility of general quality is 0.94%; and that of poor quality is zero. According to the principle of maximum membership, the grade is excellent when the membership degree of 84.45% is maximum. Therefore, quality grade of evaluation in course test quality evaluation index system is "excellent".

The result of evaluation is basically consistent with that of experts by scoring about the evaluating system. The results of fuzzy AHP comprehensive evaluation show the distribution of membership function of "excellent, good, general and poor" and more clearly reflect the objectivity of the results. Thus, fuzzy AHP comprehensive evaluation method has the relative superiority in the course test quality evaluation, and is a more objective and effective method.

5. Conclusion

This research attempts to construct a set of feasible curriculum examination quality evaluation index system which can be used for universities. The purpose is to give an effective evaluation to examination quality evaluation index system by fuzzy comprehensive evaluation method. This research has mainly completed the following work:

Firstly, it gives the evaluation index of examination quality and constructs index system according to the characteristics of examination quality. Only by selecting the appropriate indicators and establishing a reasonable evaluation system, can we achieve a scientific and fair comprehensive evaluation conclusion.

Secondly, it presents a clear definition about qualitative index and quantitative index. The selection of indicators has direct influence on the results of measurement. In order to ensure scientificity and reliability of every index in the index system, the research has determined the quantitative and qualitative indicators involved in the research through adopting classical theory of education measurement and universal standards both at home and abroad.

Thirdly, this research has designed the software system of examination quality evaluation and established the evaluation system of examination quality combining with the analytic hierarchy process and fuzzy comprehensive evaluation method.

Finally, the research has done a case analysis. By applying examination quality evaluation index system and fuzzy hierarchy comprehensive evaluation method, it analyses and

evaluates the quality of a certain course examination to demonstrate the feasibility and rationality of this method.

Acknowledgements

This research has been sponsored by the fund projects of Outstanding Young Talents in Colleges and Universities of Anhui Province and Science and Technology plan at Huainan in 2012 (No.2012SQRW032 and 2012A00914).

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