Construction of Students' Comprehensive Quality Evaluation Model based on Improved AHP

Cheng Yao, Qin Feng and Zheng Xiao

May 23, 2018

Construction of Students' Comprehensive Quality Evaluation Model based on Improved AHP

QIN feng, CHENG Yao, ZHENG Xiao

School of Computer Science and Technology

Anhui University of Technology

Ma'anshan, Anhui 243032, China

chengyao@ahut.edu.cn

Abstract—**Generally, the assessment of students in colleges is mostly based on academic performance ranking, and it is not conducive to the cultivation of all-round outstanding university students. In order to change the evaluation way of "the only achievement theory", this paper constructed the comprehensive quality evaluation model (CQE) for college students based on the analytic hierarchy process(AHP). Focusing on the limitations of subjective arbitrariness in AHP, we improved the AHP based on the stakeholder perspective(IAHP_SP). Through the experimental verification of the students' data in a university in Anhui, it shows that the comprehensive quality evaluation model of the students proposed by this study is feasible.**

Keywords—College students evaluation, AHP, ranking, comprehensive quality evaluation

I. INTRODUCTION

The students' evaluation is an indispensable part in higher education institutions, which has positive influence for promoting universities' development. This is because the evaluation of students is one of the criteria for the audit evaluation and the engineering certification in China. By analyzing students' comprehensive performance, a strategic personnel training programs can be well planned in their period of study in a college. Generally, most of higher education institutions are using the final grades to evaluate students' performance [1][2]. However, "the only achievement theory" is one-sided that cann't evaluate students in the round. Thus, constructing the CQE model of college students is essential.

The undergraduate quality model is divided into four parts, Physical-Mental Quality, Moral Trait, Scientific Literacy and Professionalism[3]. Comprehensive quality model of college students is based on Ideological-Political Quality, Knowledge Quality, Physical-Mental Quality and Creative-Practice Ability [4].Based on the principle of comprehensiveness, hierarchy, students' dominant role and feasibility, the comprehensive quality evaluation (CQE) system of college students is grouped into four aspects in Fig. 1.
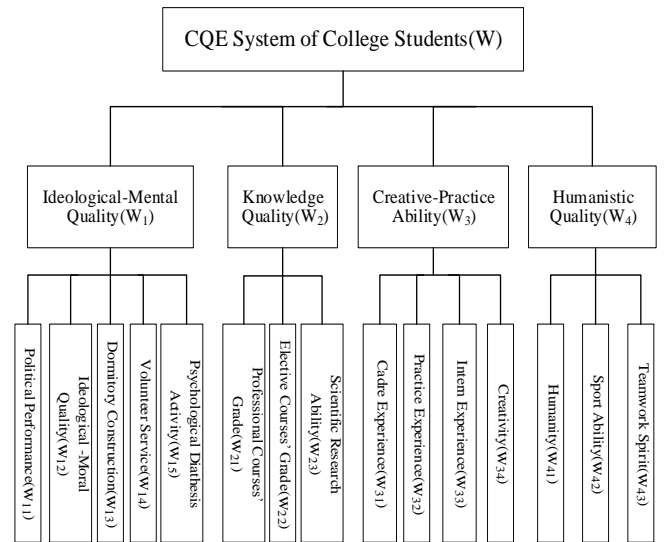
Fig. 1. CQE System of College Students

II. METHODOLOGY

A. Basic thoeory of AHP

AHP was first proposed by Thomas Saaty in the late 1970s [5], which is an operational research method combining quantitative and qualitative analysis. It can divide a complex problem into multiple components. Through the comparison of each other, the dominance of each factor is divided into orderly hierarchical structure, so as to determine the relative importance of various factors in each level [6]. The wide applicability of AHP is due to its simplicity, easy to use and great flexibility.

Applying AHP to make a structured decision making approach includes six steps: (i) define the problem and choose the criteria, (ii) construct hierarchies, (iii) use pair-wise comparison scales to have specification of numerical values in Table I [5], (iv) validate the inconsistencies in the decision process exist, including calculate maximum eigen value, consistency index (CI) CI=(λ_{max} -n)/(n-1), random consistency index (RI) and consistency ratio (CR) CR=CI/RI, revise the

process till a consensus is reached and (v) adjust integration of weight values to reach an optimum decision.

TABLE I.   IMPORTANCE INTENSITY BETWEEN TWO PARAMETERS IN AHP[5]

Importance intensity	Explanation
1	Criterion A has equal importance to criterion B
3	The importance of criterion A is moderately important to criterion B
5	The importance of criterion A is strongly important to criterion B
7	The importance of criterion A is very strongly important to criterion B
9	The importance of criterion A is extremely important to criterion B
2, 4, 6, 8	The importance of criterion A than criterion B is in the middle of the above description
Reciprocals	Used for inverse comparison

Take evaluator u_1 as an example, the first-level evaluation matrix is shown in Table II.

TABLE II.   EVALUATOR U_1'S FIRST-LEVEL EVALUATION MATRIX

X	X_1	X_2	X_3	X_4	Weight
X_1	1	1/5	1/3	1/2	0.0863
X_2	5	1	3	2	0.4909
X_3	3	1/3	1	1/2	0.2483
X_4	2	1/2	2	1	0.1745

Calculate maximum eigen value λ_{max} =4.1074 and its corresponding eigenvector is $w_A = (0.0863, 0.4909, 0.2483, 0.1745)^T$,. Then validate the inconsistencies, according to RI index[6], RI=0.90 when n=4, CR=0.0398<0.1.

AHP provided objective criteria with cluster analysis for ranking suspect entities to evaluate suspicious medical claims[7]. The comprehensive evaluation model of reservoir resettlement was established by combining information entropy theory and fuzzy AHP[8].

But, evaluators are subjected to their personal experience and they are tend to take advantage of their interest in scoring process, resulting in unreasonable calculation of indicators. In this paper, we invited several evaluators to give their evaluation matrices. Teachers gave high emphasis on knowledge ability while academic staff preferred humanistic quality. If they help each other to advance their benefits, we called them stakeholders. In order to decrease the subjective effect from evaluators, we improved AHP based on stakeholder perspective (IAHP_SP).

B. The calculation of criteria's comprehensive weight base on IAHP_SP

Let $\mathbf{A}=[x_{ij}]_{m \times n}$ be the criteria evaluation matrix, where $x_{ij}>0 (i=1, 2, …, m; j=1, 2, …, n)$ is the score of m factors' given by n evaluators.

$$\mathbf{A} = \begin{bmatrix} x_{11} & x_{12} & … & x_{1n} \\ x_{21} & x_{22} & … & x_{2n} \\ … & … & … & … \\ x_{m1} & x_{m2} & … & x_{mn} \end{bmatrix}$$

We supposed $\mathbf{A}$ has been min-max normalization processed by using:

$$x_{ij}^* = \frac{x_{ij} - m_j}{x_{ij} - M_j} \tag{1}$$

M_j is the maximum value of the j-th criterion and m_j is the minimum value of the j-th criterion.

Definition 1: Given A, the coefficient of the stakeholder r_{ik} is given as follows:

$$r_{ik} = \frac{x_i \bullet x_k}{\|x_i\| * \|x_k\|} \tag{2}$$

where $\mathbf{x}_i = (x_{i1}, x_{i2}..., x_{im})$, $\mathbf{x}_k = (x_{k1}, x_{k2}, ..., x_{kn})$, *and* $\|x_i\|$ *denotes the norm of* x_i .

Definition 2: For better describe the relationship between two evaluators, it is said to have a scalar c_{ik} called net coefficient of the stakeholders, which is an expression of positive and negative effects to counteract each other.

$$c_{ik} = r_{ik} - (1 - r_{ik}) = 2r_{ik} - 1 \tag{3}$$

These evaluators not only maximize their own benefits, but also maximize the stakeholders' benefits. These benefits are modeled as:

$$\max \sum_{k=1}^{n} c_{ik} \sum_{j=1}^{m} x_{kj} w_{ji} \tag{4}$$

where w_{ji} is the weight of criteria in perspective of the evaluator u_i.

Lemma: Criterion is assumed to be not dominant for the rest of the less important criteria, restrictive condition[11].

We defined $z_{ij} = \sum_{k=1}^{n} c_{ik} x_{kj}$ and the model is described by

$$\text{maximize} \sum_{j=1}^{m} z_{ij} w_{ji} \tag{5}$$

subject to $0.5^{m-1} \le w_{ji} \le 0.5$ and $\sum_{j=1}^{m} w_{ji} = 1$

Output: $\mathbf{W}_i = (w_{1i}, w_{2i}, ..., w_{mi})$

where $\mathbf{w}_i$ is weight vector in perspective of the evaluator u_i.

Combining (6), (7) and (8), one can calculate the evaluation value matrix $\mathbf{Y}$

$$y_{ki} = \sum\nolimits_{j=1}^{m} x_{kj} w_{ji}^* \quad (6)$$

$$\mathbf{y}_i = (y_{1i}, y_{2i}, ..., y_{ni})^T \quad (7)$$

$$\mathbf{Y} = (\mathbf{y}_1, \mathbf{y}_2, ..., \mathbf{y}_n) = \left[y_{ki} \right]_{n \times n} =$$

$$\begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \cdots & \cdots & & \cdots \\ y_{n1} & y_{n2} & \cdots & y_{nn} \end{bmatrix} \quad (8)$$

Computing maximum eigenvalue $\lambda_{\max}$ of $\mathbf{Y}$, $\mathbf{y}^* = (y_1^*, y_2^*, ..., y_n^*)$ is the eigen vector corresponding to $\lambda_{\max}$.

Definition 3: Let ψ_i be the evaluators' weight derived from $\mathbf{y}^*$:

$$\psi_i = \frac{y_i^*}{\sum_{i=1}^{n} y_i^*} \quad (9)$$

subject to $\psi_i \geq 0, \sum_{i=1}^{n} \psi_i = 1$

Calculating global weight $\mathbf{W}$ by formula $\mathbf{W} = \psi \times \mathbf{U}$, where $\mathbf{U}$ is the weight of these criteria yielded by AHP method.

III. EXPERIMENT AND DISCUSSION

A. Dataset

We obtained our dataset from a university's management systems, such as educational administration system data, scientific research management systems data and so on. The data have orderly structured and centrally classified. But it is inevitable that the data would be missing, multi-valued and invalid values. We have to preprocess the students' data as follows:

- Deleting all data records for students who change their majors, drop out of school and cheat in the exams.

- Deleting duplicate data records in order to eliminate the interference caused by duplication of data records.

- Filling the corresponding supplementary examination results for students who are absent or applying for deferment of examinations. Delete all records of the students if there are no make-up results.

- For outlier values, choosing investigated data or mean value make up.

- For the student performance of multiple make-up and multiple reexaminations results, using the first valid results for the corresponding attribute value.

We chose three students in a class take an example in Table III. These scores come from the performance of the students participate in activities except Professional Courses' Grade (W_{21}) and Elective Courses' Grade (W_{22}) which are come from students' academic grades.

TABLE III. THREE STUDENTS' SCORES

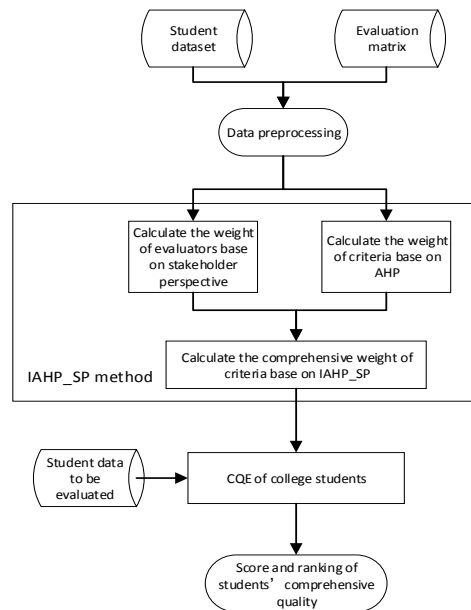| Number / Criteria	1402621	...	1402636	...	1402645	...
W_{11}	80	...	80	...	80	...
W_{12}	70	...	70	...	70	...
W_{13}	60	...	60	...	70	...
W_{14}	60	...	60	...	70	...
W_{15}	60	...	60	...	68	...
W_{21}	90.1	...	89.63	...	88	...
W_{22}	86	...	85	...	90.5	...
W_{23}	60	...	70	...	60	...
W_{31}	70	...	65	...	73	...
W_{32}	60	...	70	...	60	...
W_{33}	60	...	60	...	60	...
W_{34}	60	...	60	...	60	...
W_{41}	60	...	60	...	60	...
W_{42}	60	...	60	...	60	...
W_{43}	60	...	60	...	60	...

B. Experiment

Fig. 2. Model building flow chart

Firstly, we collected student dataset and evaluation matrices given by evaluators, then preprocessed these data. By determining the weight of each evaluator in the group, obtain the comprehensive weight of each criterion which weighted averages calculate with criteria weight by the evaluators scored.

We invited six evaluators to score the CQE system of college students. The group consists of teachers, students and academic staff.

The matrix $\mathbf{A}$ is calculated according to (2). And then we get the correlation coefficient r_{ik} between each evaluator:

$$r_{ik} = \begin{bmatrix} 1 & 0.5149 & 0.6985 & 0.8787 & 0.8355 & 0.8143 \\ 0.5149 & 1 & 0.2221 & 0.6535 & 0.7937 & 0.7160 \\ 0.6985 & 0.2221 & 1 & 0.7517 & 0.7562 & 0.8009 \\ 0.8787 & 0.6535 & 0.7517 & 1 & 0.9388 & 0.9723 \\ 0.8355 & 0.7937 & 0.7562 & 0.9388 & 1 & 0.9815 \\ 0.8143 & 0.7160 & 0.8009 & 0.9723 & 0.9815 & 1 \end{bmatrix}$$

Calculate the net profit coefficient c_{ik} between each evaluator according to (3):

$$c_{ik} = \begin{bmatrix} 1 & 0.0299 & 0.3971 & 0.7574 & 0.6711 & 0.6286 \\ 0.0299 & 1 & -0.5559 & 0.3070 & 0.5874 & 0.4320 \\ 0.3971 & -0.5559 & 1 & 0.5034 & 0.5123 & 0.6019 \\ 0.7574 & 0.3070 & 0.5034 & 1 & 0.8776 & 0.9445 \\ 0.6711 & 0.5874 & 0.5123 & 0.8776 & 1 & 0.9629 \\ 0.6286 & 0.4320 & 0.6019 & 0.9445 & 0.9629 & 1 \end{bmatrix}$$

According to (5) can obtain the value of the evaluator weight $\mathbf{W}_i^*$:

$$w_{j1}^* = \begin{bmatrix} 0.375 & 0.0625 & 0.5 & 0.0625 \end{bmatrix}^T,$$
$$w_{j2}^* = \begin{bmatrix} 0.5 & 0.0625 & 0.0625 & 0.375 \end{bmatrix}^T,$$
$$w_{j3}^* = \begin{bmatrix} 0.0625 & 0.375 & 0.5 & 0.0625 \end{bmatrix}^T,$$
$$w_{j4}^* = \begin{bmatrix} 0.375 & 0.0625 & 0.5 & 0.0625 \end{bmatrix}^T,$$
$$w_{j5}^* = \begin{bmatrix} 0.375 & 0.0625 & 0.5 & 0.0625 \end{bmatrix}^T,$$
$$w_{j6}^* = \begin{bmatrix} 0.375 & 0.0625 & 0.5 & 0.0625 \end{bmatrix}^T.$$

Combining (6) (7) and (8) can obtain $\mathbf{Y}$ and $\mathbf{y}^*$:

$$\mathbf{Y} = \begin{bmatrix} 0.4717 & 0.3720 & 0.3824 & 0.4717 & 0.4717 & 0.4717 \\ 0.5 & 0.9375 & 0.5 & 0.5 & 0.5 & 0.5 \\ 0.5260 & 0.0885 & 0.6562 & 0.5260 & 0.5260 & 0.5260 \\ 0.5789 & 0.4368 & 0.4784 & 0.5789 & 0.5789 & 0.5789 \\ 0.5086 & 0.4320 & 0.5310 & 0.5086 & 0.5086 & 0.5086 \\ 0.7981 & 0.5884 & 0.7832 & 0.7981 & 0.7981 & 0.7981 \end{bmatrix}$$

$$\mathbf{y}^* = \begin{bmatrix} 0.3235 & 0.4227 & 0.3427 & 0.3954 & 0.3652 & 0.5563 \end{bmatrix}^T$$

According to (9) can obtain the value of the evaluator weight ψ_i:

$$\psi_i = (0.1345, 0.1757, 0.1425, 0.1644, 0.1518, 0.2312)$$

The first-level criteria weight is the proportion of the first-level criterion in the student's comprehensive quality evaluation system, and the second-level criteria weight is the proportion of the second-level criterion in the corresponding first-level criterions. The comprehensive weight are the weighted average of the first-level criteria weight and the second-level criteria weight, which represents the proportion of each criterion in the entire evaluation system.

TABLE IV.   CQE SYSTEM WEIGHT DISTRIBUTION TABLE

Target	First-level Criteria	First-level Criteria Weight	Second-level Criteria	Second-level Criteria Weight	Comprehensive Criteria Weight
CQE System of College Student	W₁	0.1409	W₁₁	0.3278	0.0462
			W₁₂	0.3278	0.0462
			W₁₃	0.0610	0.0086
			W₁₄	0.1134	0.0160
			W₁₅	0.1700	0.0239
	W₂	0.4554	W₂₁	0.5396	0.2457
			W₂₂	0.1634	0.0744
			W₂₃	0.2970	0.1353
	W3	0.2628	W₃₁	0.3567	0.0937
			W₃₂	0.0870	0.0229
			W₃₃	0.1724	0.0453
			W₃₄	0.3839	0.1009
	W₄	0.1409	W₄₁	0.3000	0.0423
			W₄₂	0.1000	0.0141
			W₄₃	0.6000	0.0845

Take a student numbered 14202621, his comprehensive grade is $Y_{1402621} = \mathbf{W} \times \mathbf{X}_{1402621} = 0.00462*80 + 0.00462*70 + ... + 0.0141*60 + 0.0845*60 = 71.68$. Take the class of the three students in Table III as an example, and sort data according to the "Weighted Average Score" column. The comparison results are shown in Table V. The three students are shown in **bold**.

There are 27 students in this class, and the proportion of the first, second, third prizes is 5%, 10% and 20%. There will be 1 first prize winner, 3 second prize winners, and 5 third prize winners. The weighted average score = "W_{21} * 80% + W_{22} * 20%", "Award Prize-Score" according to the weighted evaluation score ranking, " Award Prize-Comprehension " ranked by comprehensive quality score, the "Award Change" is a representation of the change in the prize.

It can be seen from Table V that two students numbered 1402636 and 1402647 have improved their scholarship levels, the ranking of the student numbered 1402633 has decreased. And the student numbered 1402625 has been reduced from third prize to no prize. The reason is because he/she got good academic scores while did not participate in any activities, resulting in lower comprehensive score. There is no change in the award level of the rest of the students.

After obtaining the student's quality scores in all aspects, the score was introduced into the radar chart of college student comprehensive quality. Taking the students in Table III as

examples, the quality scores of various aspects were introduced into the radar chart. The results are shown in Fig. 3. It can be seen that the student's Ideological-Mental Quality and Creative-Practice Quality of number 1402645 student are better than the other two students. The Knowledge Quality and Comprehensive Quality of student numbered 1402636 are better than the other two students. Three students scored the same in Humanistic Quality.

TABLE V.   CQE SYSTEM WEIGHT DISTRIBUTION TABLE

Number	Weighted Average Score	Award Grade-Score	Compre-hensive Quality Score	Award Grade-Comprehension	Award Change
1402633	89.91	First Prize	70.71	Second Prize	↘
1402621	89.28	Second Prize	71.68	Second Prize	—
1402636	88.71	Second Prize	72.61	First Prize	↗
1402645	88.5	Second Prize	72.45	Second Prize	—
1402624	86.33	Third Prize	69.64	Third Prize	—
1402625	84.96	Third Prize	68.48	\	↘
1402644	84.3	Third Prize	69	Third Prize	—
1402642	83.28	Third Prize	68.56	Third Prize	—
1402623	83.16	Third Prize	69.18	Third Prize	—
1402639	82.68	\	68.25	\	—
1402638	82.33	\	67.67	\	—
1402635	81.51	\	67.87	\	—
1402640	79.54	\	67.59	\	—
1402647	78.87	\	68.93	Third Prize	↗
1402641	78.83	\	67.39	\	—
1402631	73.5	\	65.55	\	—
1402630	71.79	\	65.51	\	—
1402628	71.37	\	64.92	\	—
1402629	71.37	\	64.76	\	—
1402634	70.98	\	64.25	\	—
1402631	73.5	\	65.55	\	—
1402630	71.79	\	65.51	\	—
1402628	71.37	\	64.92	\	—

In the radar chart of college student comprehensive quality, students can find their own differences between other students in each aspect of quality, clarify their potential and advantages, and improve the deficiencies in order to become an all-roundly excellent college student. And the teacher can view the situation of each class of students and guide students to fill in the gaps. The higher educational departments can test the effectiveness of various quality education policies in order to formulate reasonable talent training plans and improve students' abilities in all aspects.
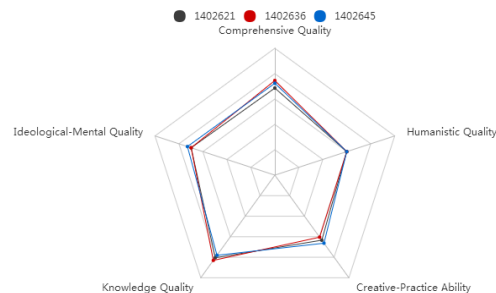

Fig. 3.   Radar Chart of College Student Comprehensive Quality

IV.   RESULT

Evaluating students' comprehensive quality performance is mostly useful to help the educators and students improving their teaching and learning process. This paper constructed a CQE model for university students. In evaluation process, we used IAHP_SP method to decrease the subjective of evaluators. Through experiment, it is proved that the weight distribution of the model is reasonable. The comprehensive quality score obtained from the model can deliver reference for education and teaching evaluation, such as class selection of outstanding student, audit evaluation, project certification and so on. It will help the educational apartments to evaluate the students' comprehensive performance in a systemic way.

REFERENCES

[1]   Fan Y, Frederick W.B. (2018). Study on student performance estimation, student progress analysis, and student potential prediction based on data mining, in press.

[2]   Qin F, Zhu L Q, Cheng Z K. Research on Student Performance Evaluation Based on Random Forest, 2017 2nd International Conference on Electrical and Electronics: Techniques and Applications (EETA2017). 2017, pp. 387-392.

[3]   Zheng Y. A Study on Construction and Application of Competency Model For College Students. Wuhan, Hubei: Wuhan University, 2013, pp. 120-122.

[4]   Zhang L T, Liu D H. Research on the evaluation system of students' comprehensive quality base AHP. Chinese Vocational Chinese Vocational and Technical Education. 2015, pp. 39-42.

[5]   T L Saaty. A scaling method for priorities in hierarchical structures. J Math Psychol, vol. 15, pp. 234-281, June 1977.

[6]   T L Saaty. The analytic hierarchy process: planning, priority setting, resource allocation. New York: McGraw-Hill International Book Co. 1980, pp. 287.

[7]   T Hillerman, J C Souza, A C Reis, R N Carvalho. Applying clustering and AHP methods for evaluating suspect healthcare claims. Journal of Computational Science, vol. 19, pp. 97-111, February 2017.

[8]   Gong J, Hu N, Cui X, Wang X D. Rock burst tendency prediction based on AHP-Topsis evaluation model. Chinese Journal of Rock Mechanics & Engineering, vol. 33, pp. 1442-1448, July, 2014.

[9]   Chaudhary P, Chhetri S K, Joshi K M, B M Shrestha, P Kayastha. Application of an Analytic Hierarchy Process (AHP) in the GIS interface for suitable fire site selection: A case study from Kathmandu Metropolitan City, Nepal. Socio-Economic Planning Sciences, vol. 53, pp. 60-71, October, 2016.

[10] Zeynep D U. (2018). Assessment of techno-entrepreneurship projects by using Analytical Hierarchy Process (AHP). Technology in Society, in press.

[11] Yi P T, Guo Y J. Multi-attribute decision-making method based on competitive view optimization under condition of weights nondictatorship. Control and Decision, vol. 22, pp. 1259-1263, November, 2007.