Research on Graduate Education Quality Evaluation Based on Combination Empowerment and Comprehensive Fuzzy Model

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Abstract. Graduate education quality evaluation is an important part of higher education evaluation. This paper designs an evaluation system that can fully reflect the quality of graduate education, and then combination weighting method and comprehensive fuzzy model were used to verify it. Combining subjective analytic hierarchy process with objective entropy, 10 indexes are weighted and a reasonable weight coefficient vector is obtained. Taking Tianjin University as an example, the comprehensive ranking of postgraduate education quality in 20 colleges of Tianjin University is calculated by using the comprehensive fuzzy evaluation model. The study found that the matriculate quality, scientific research environment, graduate research level and employment ability are the main factors affecting the evaluation of graduate education quality whose contribution rate is as high as 85% and the quality of postgraduate education in science and engineering colleges is significantly higher than that in humanities colleges.

1. Introduction

Higher education is the main approach to cultivate high-level talents an important component of the national innovation system, which has an important impact on the economy and society of a country[1]. In 1978, Chinese graduate students resumed enrollment. By 2017, the enrollment of Postgraduates in China has reached 806,000, the number of Postgraduates in school has reached 2.64 million, and the number of graduates has reached about 580,000[2]. This shows that China's higher education has made remarkable progress in the past 40 years of reform and development. However, the multiple growth in quantity can not fully reflect the actual development level of higher education in China. With the increasing dependence of the market on knowledge productivity[3], the diversification of the labor market demand makes graduate education begin to face more goals and demands, and the requirements for graduate students' innovative ability, knowledge transfer ability and other comprehensive qualities are also increasing, which makes the evaluation of the output quality by various training units can no longer focus solely on academic level, Therefore, the improvement of postgraduate education quality should be re-examined.

In September 10, 2018, Chinese President Xi Jinping stressed in the keynote speech of the national education conference that we should speed up the short board of education and resolutely overcome the problem of education evaluation by grading, studying, diploma and thesis, which help fundamentally solve the problem of baton in education quality evaluation result training innovative, compound and applied talents. This fully shows that it is necessary to construct a scientific evaluation
system for the quality of postgraduate education to promote the development of higher education in China. In addition, with the vigorous development of knowledge economy, the training objectives, training modes and evaluation methods of postgraduate education have changed greatly, which makes the evaluation index of postgraduate quality become more and more pluralistic, and the single evaluation criteria are no longer applicable. It is urgent to put forward a more comprehensive evaluation system of postgraduate education quality.

The quality of postgraduate education has become a worldwide concern. Some studies have suggested that the quality of higher education can be defined[4], and high-quality higher education should include the quality of students, faculty credentials, academic features, and administrative supports [5]. Teachers' qualifications and teaching quality are also regarded as an important link to measure the quality of higher education. The quality here includes personal quality and professional quality. Personal qualities include general personal qualities, kindness, leadership and professional attitudes. However, professional qualities mainly refer to teaching knowledge[6,7]. Others believe that the quality system of graduate students should be built around the internal and external guarantee mechanism of training units and the social benefits of personnel training. The internal evaluation is mainly based on the basic curriculum learning ability, practical skills and scientific research level, while the social evaluation mainly focuses on the investigation of school running conditions and teachers' level.[8] The quality of education is influenced by many factors, but the factors of academic research within the university are undoubtedly very important for the evaluation of the quality[9].

On the evaluation method, Accelerated genetic algorithm, projection pursuit classification model, principal component analysis, analytic hierarchy process, data envelopment method, fuzzy neural network and input-output method are all important means to evaluate the quality of graduate education[10,11,12]. However, due to the different evaluation motivation and evaluation indicators, different evaluation methods often produce different evaluation results, which cannot be used as a direct reference. Based on this, according to the needs of talent training in universities of China, the evaluation system of graduate education quality is constructed. Then, the analytic hierarchy process and the entropy weight method are combined to determine the main factors then, taking the data of 20 colleges in Tianjin University as an example, a fuzzy comprehensive evaluation model is used to further quantitatively evaluate the quality of postgraduate education in Colleges and universities.

2. Graduate Education Quality evaluation System

Educational quality can be defined in many ways. Koslowski argues that academics are more likely to use resources than performance to define the quality of higher education, such as personal reputation, the number of publications and the number of courses taught[13]. Mitchell defines the quality of education from the perspective of stakeholders, quantifiable elements, curriculum design elements and external standards[14]. Based on a series of literatures, the following rules should be followed in the construction of graduate education quality evaluation system.

2.1. Construction Principles

2.1.1. Pluralism. Freeman explicitly put forward stakeholder theory, and the theory emphasizes that the development of anything is inseparable from the input or participation of various stakeholders[15]. The training process of graduate students involves many stakeholders, such as government, schools, enterprises, students, etc. Therefore, the research on the evaluation of graduate education quality should also adhere to the pluralism. Firstly, starting from the training units such as schools and colleges, this paper considers the investment of policy support such as funds, the construction of teachers, the environmental structure of scientific research and professional level support in the training process. Secondly, from the students' point of view, consider their satisfaction. Then, starting from enterprises, the higher requirements of the labor market for the quality of talent output are included.

2.1.2. Quantifiable. The evaluation data of postgraduate education quality must be quantifiable[16]. Only in this way can colleges and universities diagnose their shortcomings in the process of personnel training and provide theoretical support for improving the quality assurance system. This requires that
the data to evaluate the level of each index is measurable, otherwise the evaluation system will lose its application value. Therefore, the evaluation system constructed in this study will eliminate unquantifiable indicators and inaccurate elements, and strive to achieve scientific and measurable data support.

2.2. Structure of evaluation system

Combined with the existing literature and the principles of index construction, the following structure of evaluation system is obtained in Table 1.

Table 1. Graduate Education Quality Evaluation System.

| First level index | Second level index |
|-------------------|--------------------|
| matriculate quality | policy support |
| Input layer | scientific research environment |
| | college construction |
| | curriculum construction |
| | graduate research level |
| | Innovation |
| Output layer | entrepreneurship ability |
| | professional knowledge level |
| | employment ability |

3. Methodology

In order to construct a fuzzy evaluation system, it is necessary to first confirm the weight coefficients of each index. The methods to determine the weight include subjective, objective and combinatory empowerment. Among them, subjective empowerment is given by experts, which can be used for reference. The common methods are chromatography analysis, Delphi method and factor comparison method. Traditional subjective empowerment often has the disadvantage of strong subjective preference. The objective empowerment method can make up for this disadvantage by relying on actual data. Common objective empowerment methods include multi-objective programming method, principal component analysis method, mean square error weight method, entropy method, etc.

However, the generality of objective weighting method is poor, which can not reflect the importance of different indicators. Therefore, combined with the evaluation system of postgraduate education quality and the applicability of each weighting method, this study uses the combination weighting method, the comprehensive analytic hierarchy process and the entropy method to determine the weight. On this basis, a comprehensive fuzzy evaluation model is constructed, and the evaluated objects are evaluated by the comprehensive scores obtained from the calculation.

3.1. Index weight

3.1.1. Analytic Hierarchy Process. From the first level of the evaluation system, the corresponding indicators of the higher level of membership are constructed into a pair of comparison matrix until the last level, forming an n-dimensional judgment matrix. The value of the importance degree of the two relative factors can be obtained by referring to the nine-scale table (in Table 2), and the final 10-order judgment matrix can be obtained which was called $W_i$. 
Table 2. The value of the importance degree of the two relative factors

| Description            | Value |
|------------------------|-------|
| extremely important    | 9     |
| very important         | 7     |
| important              | 5     |
| slightly important     | 3     |
| Equally important      | 1     |
| slightly unimportant   | 1/3   |
| unimportant            | 1/5   |
| very unimportant       | 1/7   |
| extremely unimportant  | 1/9   |

3.1.2. entropy method. Since all 10 indicators are benefit indicators, that is to say the higher the value, the better, according to the formula:

\[ x_{ij} = \frac{x_j - x_{\min}}{x_{\max} - x_{\min}} \]  

Where, \( i \) is the \( i \)-th evaluated object, and \( j \) represents the \( j \)-th evaluation indicator, \( x_{ij} \) is the value of the \( j \)-th indicator of the \( i \)-th object to be evaluated. Then calculate the proportion of the \( j \)-th indicator in the \( i \)-th evaluation object:

\[ p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \]

Where, \( 0 \leq p_{ij} \leq 1 \) and \( i = 1,2, \ldots, n, j = 1,2, \ldots 10 \).

Next, calculate the entropy value of \( j \)-th:

\[ E_j = -K \sum_{i=1}^{m} p_{ij} \ln p_{ij} \]

Where, \( E_j \geq 0 \) and \( K = 1/\ln(n) \). And \( i = 1,2, \ldots, n, j = 1,2, \ldots 10 \).

Then, calculate the Weight Value of \( j \)-th evaluation indicator by entropy method:

\[ W_j = \frac{(1 - E_j) \sum_{i=1}^{m} d_j}{\sum_{i=1}^{10} (W_1 \ast W_2)} \]

To sum up, the entropy weight vector \( W_2 \) for 10 indexes is obtained by using the method of entropy value.

3.1.3. Combination Empowerment. Before weighting combinations, we first test Pearson consistency coefficients of subjective and objective weighting results. The purpose is to verify the consistency of subjective and objective results, and to find a suitable combination method on the basis of the Pearson consistency coefficients. SPSS software is used for analysis. If the results of subjective and objective tests are consistent and the difference is small, next we can use multiplication synthesis for combination weighting. Then there are:

\[ W = W_1 \ast W_2 \sum_{i=1}^{10} (W_1 \ast W_2) \]

3.2. Comprehensive Fuzzy Model

3.2.1. Determine the set of factors. According to the designed evaluation system, the quality of postgraduate education in Colleges and universities is ultimately affected by 10 indicators:

\[ U = [U_1, U_2, U_3] \]

3.2.2. Establish evaluation rank domain. In order to better evaluate the quality of graduate education in universities, we make the following provisions on the grade matrix of the evaluation system:

\[ V = [A, B, C, D, E], \text{thus } V = [1, 0.8, 0.6, 0.4, 0.2]. \]

3.2.3. Establish the Fuzzy Relation Matrix. When determining the membership degree of each index, it is necessary to normalize the index according to its attributes in order to ensure the matrix operation of the index data. We define the \( M \)-th unit to be evaluated as \( y_m \), then \( y = \sum y_m / m \), and the membership function is:
Then, the fuzzy relation matrix is:

\[
R = \begin{bmatrix}
    r_{11} & r_{12} & \cdots & r_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    r_{m1} & r_{m2} & \cdots & r_{mn}
\end{bmatrix}
\]  

(8)

4. Model application and result analysis

4.1. Data sources

In order to verify the application value of the graduate education quality evaluation system, this paper evaluates the graduate education quality of 20 colleges of Tianjin University. The data collection range is from 2013 to 2018. To ensure the rationality of weights assignment, we consulted 12 experts, including master's supervisor, leaders of university employment centers and head of human resources. Meanwhile, questionnaires on the evaluation of teaching quality were distributed to the students of various colleges. The rate of return of the questionnaires was 85%. Therefore the data were representative and could be processed and analyzed.

4.2. Result analysis

Using MATLAB to calculate the 10-order judgment matrix, we calculated \( \lambda_{\text{max}} = 31.3 \). In order to ensure rationality, it is necessary to verify the random consistency ratio of the judgment matrix CR. According to \( CI = (\lambda_{\text{max}} - n)/(n-1) \), then \( CI = 0.04 \), and \( CR = CI/RI = 0.03 < 0.1 \), the consistency test is passed, so the weights are reasonable. And then the objective weights of the seven indicators are determined according to the entropy method formula, and the weight vector is obtained by using EXCEL for data processing. Test the consistency of subjective and objective weight results, Pearson consistency coefficient test, the P value is 0.02 < 0.05, the results show that it has significance, then use multiplication synthesis, the final calculation of the weight results (as shown in Table 3).

| First level index     | Second level index             | Value of weight |
|-----------------------|--------------------------------|-----------------|
| matriculate quality   | 0.4621                         |                 |
| policy support        | 0.0015                         |                 |
| scientific research environment | 0.1925                     |                 |
| college construction  | 0.0086                         |                 |
| curriculum construction | 0.0153                      |                 |
| graduate research level | 0.1001                     |                 |
| innovation            | 0.0400                         |                 |
| entrepreneurship ability | 0.0471                     |                 |
| professional knowledge level | 0.0037                 |                 |
| employment ability    | 0.0838                         |                 |

Table 3. Evaluation of Graduate Education Quality in Tianjin University Colleges.

The weight represents the importance of the index in evaluating the quality of graduate education in colleges. Table 3 shows that in the evaluation system of postgraduate education quality, the more
important indicators are the number of postgraduate students, the number of guaranteed postgraduate students, the number of double-class construction universities and disciplines, the scores of postgraduate students and guaranteed postgraduate students, the number of key laboratories and research centers, the amount of research funds, papers and competitive research projects, and the employment rate and the weight of the above indicators is as high as 84%. Among them, the weight of indicators reflecting matriculate quality is 46%. This shows that matriculate quality, scientific research environment, graduate research level and employment ability are the main factors affecting the evaluation of graduate education quality.

Through the calculation of MATLAB, the grade table reflecting the quality of graduate education in each college of tianjin university is obtained (as shown in Table 4).

| College                                         | Rank | Score |
|-------------------------------------------------|------|-------|
| College of Mechanical Engineering               | A    | 0.89  |
| College of Architectural Engineering             | A    | 0.855 |
| College of Precision Instruments and Electronic Engineering | A    | 0.85  |
| Chemical Engineering College                     | A    | 0.847 |
| College of Electrical Automation and Information Engineering | A    | 0.838 |
| College of Management and Economics              | A    | 0.822 |
| College of Pharmaceutical Science and Technology | A    | 0.803 |
| College of Architecture                          | B    | 0.781 |
| College of Materials Science and Engineering      | B    | 0.771 |
| College of Computer Science and Technology       | B    | 0.764 |
| Software College                                 | B    | 0.696 |
| Microelectronics College                         | B    | 0.625 |
| College of Science                               | C    | 0.564 |
| College of Mathematics                            | C    | 0.529 |
| College of Life Sciences                         | C    | 0.459 |
| College of Education                             | D    | 0.398 |
| law College                                      | D    | 0.38  |
| Marxist College                                  | D    | 0.379 |
| College of Foreign Languages and Literature       | D    | 0.35  |

As the research results show, the average score of evaluation of graduate education quality of Tianjin University is 0.66, and overall, its quality is in a extremely excellent level. In addition, the range value of graduate education quality in different colleges is up to 0.54. That means there are significant differences in the quality of graduate education in various colleges: The results of data analysis show that the graduate education quality of seven institutes, such as College of Mechanical Engineering, College of Architectural Engineering, College of Precision Instruments and Electronic Engineering, Chemical Engineering College, College of Electrical Automation and Information Engineering, College of Management and Economics and College of Pharmaceutical Science and Technology, which are outstanding with ranking A. Among them, the comprehensive score of College of Mechanical Engineering with the best quality is as high as 0.89.

The quality of postgraduate education in five institutes such as College of Architecture, College of Materials Science and Engineering and so on is excellent, with an average score of about 0.722. Although the Software College and Microelectronics College are both in Grade B, there are some differences in their graduate education quality. According to the result of deviation, the comprehensive score of graduate education quality in software College is 2.8% higher than the average level of Tianjin University, while that of Microelectronics College is 4 % lower than the overall average level.

The results of graduate education quality in the colleges of science, mathematics and life sciences are at a general level. Finally, the quality of graduate education in Rank-D colleges are as follows:
College of Education, law College, Marxist College and College of Foreign Languages and Literature, which has the average score of the above-mentioned colleges for only 0.377. According to the data analysis of 20 colleges, the quality of graduate education in science and engineering colleges is generally higher than that in humanities colleges and it is urgent to improve the quality of graduate education in humanities colleges.

5. Conclusion

This paper evaluates the quality of postgraduate education in 20 colleges of Tianjin University from 2014 to 2018 by using the combination weighting method and the comprehensive fuzzy evaluation model, so as to clarify the development law and existing problems of the quality evaluation of postgraduate education in Colleges or universities, and draw the following four main conclusions.

Matriculate quality is an important factor affecting the quality of postgraduate education. From 2014 to 2018, the proportion of students' background in the evaluation of graduate education quality in universities is as high as 46%. This shows that there is a close relationship between matriculate quality and the quality of education. Matriculate quality is more and more important for evaluating the quality of graduate education.

The level of scientific research and employment ability are important considerations to measure the quality of postgraduate education. According to the evaluation indicators, the indicators reflecting the research level and employment ability of graduate students are the number of papers published, the number of competitive research projects, the employment rate. Their weight in the evaluation of the quality of graduate education in Colleges and universities accounts for nearly 20%, which shows the importance of graduate research ability and employment ability.

Scientific research environment is an important consideration in evaluating the quality of graduate education in Colleges and universities. According to the results of empowerment, the indicators reflecting the scientific research environment include the number of research centers, key laboratories and research centres, which contribute 19% to the evaluation of the quality of graduate education in universities. Therefore, improving the scientific research environment should become a new focus of developing the quality of graduate education in universities.

There are obvious differences in the quality of postgraduate education among different types of colleges. The quality of postgraduate education in science and engineering colleges is generally higher than that in humanities colleges. According to the analysis results and the characteristics of the research objects, Tianjin University belongs to the Polytechnic School, which pays more attention to science and engineering, thus its research environment, development ability and so on are also relatively dominant. In contrast, the development of humanities colleges is still insufficient, and the overall quality of postgraduates in the colleges of humanities is low, so there is a phenomenon of unbalanced development of disciplines.

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