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A Study for Determining Critical Factors of Teaching Quality by Genetic algorithm

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ABSTRACT: Teachers play a crucial role in shaping the curriculum and implementing teaching strategies. Effective evaluation tools are essential for assessing teaching performance, aiding teachers in evaluating their effectiveness, and enhancing overall teaching quality. A tailored teaching quality evaluation system is developed based on the unique characteristics of university educators. Feedback on teaching quality is gathered from students through a comprehensive questionnaire survey, yielding 381 valid responses. The study employs a genetic algorithm to identify critical factors within the teaching quality evaluation framework. The findings highlight the significance of factors such as punctuality in conducting classes, relevance of practical teaching content to subject development, and engaging teaching methods that deviate from traditional approaches. Correlation analysis of these factors offers valuable insights to guide decision-making for university administrators and faculty.

KEYWORDS: Teacher; teaching quality; genetic algorithm; critical factor

I. INTRODUCTION

The academic performance of colleges and universities is intricately linked to the effectiveness of their educators [21]. Enhancing the instructional standards upheld by teachers stands as a pivotal factor in ensuring the enduring progress of academic institutions. The ongoing trend of expanding student enrollment in higher education has presented a series of challenges for college instructors, including an overwhelming teaching workload and mounting pressure to engage in scholarly research activities. These factors have variably influenced the overall quality of instruction [22]. Consequently, there is a pressing need to address issues related to teaching methodologies and elevate the standard of teaching within the academic sphere.

In the field of higher education, teaching quality evaluation has become an effective organizational control tool and management means. At present, the research on teaching quality evaluation mainly focuses on three aspects: one is the evaluation subject; the other is the evaluation content; the third is the evaluation method. (a) In terms of evaluation subject, some scholars have constructed the evaluation subject system of classroom teaching quality in colleges and universities according to the stakeholder theory [4], and some scholars point out that colleges and universities should highlight the subject position of students and attach importance to students 'satisfaction with teaching quality [9,13]. (b) In terms of evaluation content, some scholars have established an evaluation index system for classroom teaching quality based on AHP [4,16], some scholars have established an effective evaluation index system for teaching quality based on the professional characteristics and teaching practice of engineering colleges [8,11], and some scholars have established an evaluation index system for practical teaching quality of applied colleges based on constructivism theory with student satisfaction of practical teaching quality as the evaluation target [1,19]. (c) In terms of evaluation methods, there are many evaluation methods proposed at home and abroad, such as AHP, ANP, PCA, etc. However, according to the existing literature and evaluation practice, most colleges and universities in our country use students as the main body of teaching quality evaluation, while traditional Likert scale can not deal with the uncertainty and inaccurate cognition of students in evaluation, so fuzzy theory can effectively evaluate appropriate values.

This study aims to assess the significance of individual criteria in evaluating teaching quality in a more refined manner. A well-structured teaching quality evaluation system tailored to the specific teaching attributes of university educators is essential. Initially, student satisfaction evaluations regarding teaching quality are gathered through a

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questionnaire survey. Subsequently, the collected questionnaire data is processed using fuzzy theory to account for its inherent uncertainties. Next, an optimization process is conducted utilizing genetic algorithms to ascertain the relative importance of each criterion. This approach aids educational institutions in identifying critical factors influencing teaching quality satisfaction, offering valuable insights for school administrators and teachers to enhance overall teaching quality.

II. FUNDAMENTAL THEORY

2.1 Genetic algorithm

The foundational concept of genetic algorithms was introduced by Holland in 1975 [5], drawing inspiration from the optimization process observed in natural selection. This approach mirrors Darwin's principle of natural competition and the survival of the fittest, aiming to mimic the mechanisms that drive evolutionary processes.

He proposed a novel approach to addressing the issue by conceptualizing the solution as a genotype of chromosome structure. In this framework, each chromosome within the solution space corresponds to a potential solution, while the phenotype signifies the interpretation conveyed by the solution to the problem. Rooij et al. highlighted the fundamental genetic algorithm operators: reproduction, crossover and mutation [17]. At the outset of the algorithm, an initial population is created, with chromosomes undergoing reproduction via crossover, mutation, and other pertinent operations. As the number of chromosomes in the population reaches the predetermined maximum threshold, the process halts, and the cohort is evaluated. Each chromosome's fitness value is assessed within the group, enabling the identification and removal of suboptimal chromosomes.

Goldberg proposes a mechanism where the mother of a species actively chooses individuals with superior traits[3]. Through random genetic exchanges, she aims to generate offspring that surpass her own qualities. By iteratively repeating this process, the quality of the chromosomes improves progressively, becoming increasingly well-suited to the environmental conditions provided. This iterative selection process ultimately leads to the emergence of the most adaptable species, representing the optimal solution to the prevailing challenges.

2.2 Teaching quality

The evolving educational landscape has heightened societal expectations for school education, placing a growing emphasis on educational quality. The quality of education stands as a fundamental pillar in augmenting learning outcomes and ensuring educational excellence [12]. Consequently, teachers have emerged as the primary assets in school education, wielding significant influence over educational quality. They serve as the linchpins in schools, not only safeguarding students' learning efficacy but also acting as gatekeepers within educational institutions. Teachers represent the most crucial resources in schools, exerting the most direct impact on the educational standard. The UK Government's White Paper "The Importance of Teaching," released in 201, delineates four foundational policies for schools, teachers, students, and principals. These policies are designed to elevate educational quality, bolster learning outcomes, and enhance the overall educational milieu [23]. According to Liu's study [15], education entails a dual feedback mechanism involving both "teaching" and "learning". It involves a complex series of interactive feedback loops between educators and learners in educational settings, as well as a dynamic elucidation of educational material by instructors during real-time interactions.Liao [10] characterizes it as "the extent to which education drives students towards achieving anticipated educational outcomes, encompassing learning endeavors, influence on student attributes, educational resource content, and instructional process design." Chiang and Cheng [2] propose that "educational quality research focuses on the collaborative educational communication endeavors involving teachers, aiming to achieve harmony between teaching and learning, fostering mutual progress as the objective of classroom educational communication, which is a shared aspiration of both educators and learners."

Hence, the education aims to attain valuable learning objectives. Teachers and students exchange emotions, skills, and knowledge through interactive feedback processes. Teachers must plan and utilize effective strategies and educational materials to improve students' comprehension of significant learning objectives.

III. RESEARCH DESIGN

3.1 Data description

The data pattern below displays the performance values of each criterion of teaching quality and the overall evaluation provided by n students in the questionnaire.

The table 1 assigns f_{ij} and d_i to semantic words (e.g., strongly disagree, disagree, agree, strongly agree) using triangular fuzzy numbers. That is, f_{ij} and d_i represent the fuzzy performance values of x_j as indicated by the i-th respondent. Both f_{ij} and

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d_i are evaluated on the 5-point Likert Scale, with d_i serving as a sample to characterize the output.

Table 1: The data type of questionnaires

Criterion				Overall evaluative value
x_1	x_2	…	x_m	
f_{11}	f_{12}	…	f_{1m}	d_1
f_{21}	f_{22}	…	f_{2m}	d_2
⋮	⋮	…	⋮	⋮
f_{n1}	f_{n2}	…	f_{nm}	d_n

3.2Problem design

Let S denote a parameter set comprising values for w_{ij}^a and w_{ij}^o specified in a hierarchical structure. The task of determining w_{ij}^a and w_{ij}^o involves framing monocular optimization, as depicted in equation (1) below,

Minimize e(S) (1)

where e(S) represents the total squared error derived from S. Let $d_i$denote the vector value (f_{i1}, f_{i2},….,f_{im}). Subsequently, consider the triangular fuzzy numbers of o_i or d_i denoted as (o_i^L, o_i^M, o_i^U) and (d_i^L, d_i^M, d_i^U) respectively, where o_i^U and o_i^L represent the upper and lower boundary values of the membership function of d_i, and d_i^U and d_i^L denote the upper and lower boundary values of the membership function of o_i. Moreover, e(S) is defined based on the disparity between the actual output (e.g., d_i) and the mapped fuzzy objective (e.g., o_i).

e(S)=

$$\sum_{i=1}^{n}((o_i^L - d_i^L)^2 + (o_i^M - d_i^M)^2 + (o_i^U - d_i^U)^2) \quad (2)$$

The term “single-objective” in genetic algorithms pertains to versatile optimization methods applicable to this issue through fitness functions, as depicted below: where f(S) represents the fitness value of S.

$$f(S) = \frac{1}{e + (S)} \quad (3)$$

The fitness of a set of connection weights is regularly adjusted in every generation of the genetic algorithm. Consequently, the primary aim of genetic algorithms is to identify a parameter set of S through the minimization of the RMSE.

3.3Genetic operations

Let N_{pop} and N_{gen} denote the population size and total genetic generations, respectively, with binary string coding. Initially, N_{pop} string is created with each bit randomly set to 1 or 0 with a probability of 0.5. After evaluating chromosome fitness in the current population, the genetic algorithm executes selection, mating, and mutation operations to produce the updated N_{pop} string for the subsequent population.

To generate new strings for the next population, a roulette wheel is employed. Two strings are randomly chosen from the current population, and the string with the higher fitness is added to the mating pool. This process is repeated N_{pop} times until the mating pool contains N_{pop} strings. Subsequently, crossover and mutation operators are used to select parents and produce offspring. Specifically, single-point crossover (with a crossover rate of p_c) is used to exchange information between two strings, and the resulting offspring replace their parent strings. Additionally, each character in the string has a mutation probability (p_m) of being modified by the mutation operator during execution. The goal of this study is to determine the connection weights in the evaluation framework, which are generated by minimizing the RMSE [7]. Hence, its related steps are as follows [7]:

Step 1: Initialization.Randomly generate a binary string for N_{pop} and set 0 to t.
Step 2: Calculate the fitness value.Calculate the fitness value for each string in the current population.
Step 3: Terminated test.Determine the stopping condition based on the number of terminated test generations. If the condition is unmet, continue; if met, the algorithm concludes, with the chromosome of maximum fitness as the optimal solution.
Step 4: Generate New Strings. Create N_{pop} new strings using selection, crossover, and mutation from the existing population.
Step 5: Elitist strategy. Randomly removeN_{rem} strings from the new N_{pop} strings, then incorporate the N_{rem} best strings from the current population to form the next generation. Update t to t+1 and return to step 2.

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IV. EMPIRICAL STUDY

4.1 Construction of teaching quality evaluative framework

Drawing on prior research findings [1,8,13,18,20,22], the study developed a teaching quality evaluative framework (refer to Table 2) based on the current assessment criteria used in higher education institutions. The Delphi method was used to validate the framework, involving a panel of eight experienced faculty members from a management college (refer to Table 3). The quartile difference technique was utilized to determine if the criteria had achieved a consensus among the expert panel. Criteria with an interquartile difference ≤ 0.5 and an importance score > 5 were retained as achieving consensus. Analysis of the survey results (refer to Table 4) confirmed a consensus among the expert panel, indicating the validity of the evaluative framework.

Table 2: The evaluative framework of teaching quality

Dimension	Criterion	Coding
Teachers 'ethics	Caring for students, harmonious relationship between teachers and students.	c_{11}
	Enthusiasm and dedication to teaching, full preparation of lessons and dedication to lectures.	c_{12}
	Classes start and end on time and do not adjust (stop) classes at will.	c_{13}
Teaching content	The textbooks are selected appropriately, provide extracurricular reference materials and are effective.	c_{21}
	The teaching content is practical and can be updated according to the development of the subject.	c_{22}
	The lectures are focused, detailed and appropriate, and the difficulty is appropriate.	c_{23}
	The teaching content can give students inspiration to think, associate, and innovate.	c_{24}
Teaching skills	Vivid teaching, not scripted, proper method.	c_{31}
	Seriously organize teaching, teach students according to their aptitude, and moderate the pace of lectures.	c_{32}
	Good at mobilizing students 'enthusiasm and encouraging students to express their views.	c_{33}
	Strengthen process teaching, pay attention to cultivating students 'learning methods and thinking modes.	c_{34}
	Fair and appropriate evaluation methods for learning.	c_{35}
Learning tasks	Appropriate learning tasks, reasonable assignments, closely related to the course content.	c_{41}
	Careful tutoring, patient answering questions, serious correction of homework.	c_{42}
Teaching effects	Students master the basic knowledge and skills of the course.	c_{51}
	Students have increased their interest in the subject and broadened their knowledge.	c_{52}

Table 3: The membership of expert groups

ID	1	2	3	4
Department	Marketing	Accounting	Business Administration	Marketing
Job title	Assoc. Prof.	Lecturer	Prof.	Assoc. Prof.
Working years	3 years	4 years	4 years	6 years
ID	5	6	7	8
Department	Business Administration	Accounting	Accounting	Marketing
Job title	Assoc. Prof.	Prof.	Assoc. Prof.	Lecturer
Working years	10 years	13 years	4 years	1years

4.2 Survey data

Evaluation data on the teaching quality of 10 teachers in a management college in Guangdong province were collected through questionnaires. A total of 500 questionnaires were distributed, with 462 valid responses received after filtering out invalid ones. Each sample in the questionnaire data includes 16 evaluation indicators (c_1 to c_{16}) and an

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overall evaluation value (d). Respondents used a five-point scale to provide subjective assessments, filling in triangular fuzzy numbers. The data will be normalized to the [0, 1] interval before applying a genetic algorithm for training.

Table 4: The results of quadrant

Evaluative criterion	Results			Evaluative criterion	Results		
	Importance	QD	Consistency		Importance	QD	Consistency
c_{11}	5	0.5	Consistency	c_{32}	6	0	Consistency
c_{12}	5.9167	0	Consistency	c_{33}	5.9167	0	Consistency
c_{13}	6	0	Consistency	c_{34}	5	0.5	Consistency
c_{21}	5.0833	0	Consistency	c_{35}	5.0833	0	Consistency
c_{22}	6	0	Consistency	c_{41}	5.5	0.5	Consistency
c_{23}	5.9167	0	Consistency	c_{42}	5	0.5	Consistency
c_{24}	5.5	0.5	Consistency	c_{51}	5	0.5	Consistency
c_{31}	5.5	0.5	Consistency	c_{52}	5	0.5	Consistency

4.3Parameter settings

This study refers to Osyczka's settings [16], and the parameters are described as follows:
(1) $N_{pop} = 150$.
(2) $N_{gen} = 2000$.
(3) $N_{rem} = 2$.
(4) The string length is set to 10 because each parameter requires three-digit precision.
(5) The $p_c = 0.9$ and $p_m = 0.01$. The setting of pc is used to provide exploration with more solution space; The setting of p_m is to avoid excessive interference.

4.4The analysis of results

Table 5 presents the findings regarding the relative importance for dimensions. The data illustrates that students prioritize teaching content, teacher ethics, and teaching skills. It is evident that teachers need to enhance the quality of their teaching based on these aspects. The analysis reveals that teaching content (0.269) is deemed the most crucial factor in teaching quality, as it is more tangible for students during classes. Following this, teacher ethics (0.264) is considered significant from the perspective of students, who value teachers' care, active engagement in teaching, punctuality, and consistency in class arrangements. Lastly, teaching skills structure (0.222) holds importance as it pertains to how teachers design, organize, utilize, and foster teaching skills to ensure students' engagement in the learning process, thereby preventing monotony in the classroom.

Subsequently, the teaching effects (0.127), aimed at equipping students with fundamental course knowledge and skills while expanding their breadth of understanding. However, this impact typically manifests gradually and modestly, with notable outcomes often contingent upon progression to more advanced coursework. Following this is the learning tasks (0.118), where students perceive assignments as most beneficial when closely aligned with course content, facilitating inquiries to instructors for guidance and thorough responses. Collectively, the initial three elements constitute nearly 76% of the preface's structure, underscoring the imperative of commencing teaching quality enhancements from these foundational components.

Table 5: The degrees of relative importance of dimensions

Dimension	Teaching content	Teachers 'ethics	Teaching skills	Teaching effects	Learning tasks
Weighting	0.269	0.264	0.222	0.127	0.118
Ranking	1	2	3	4	5

Table 6 presents the relative importance of the various criteria. The criterion with the highest importance is "classes start and end on time and do not adjust (stop) classes at will (c_{13})". This reflects the importance students place on having classes start and end as scheduled, without unplanned disruptions. Minimizing schedule changes allows students to effectively manage their time, ensuring adequate rest and preparation for subsequent classes. The second most importance criterion is "the teaching content is practical and can be updated according to the development of the subject (c_{22})". Students value course content that is current and applicable, keeping pace with the latest advancements in the field. This necessitates that instructors supplement textbook knowledge with up-

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to-date information gathered from their own scholarly activities and engagement with the subject matter.

The third crucial criterion is "vivid teaching, not scripted, proper method" (c_{31}). Students expect instructors to deliver engaging and spontaneous lessons to sustain their interest in learning. A scripted approach may lead to a stifling classroom environment, causing students to feel fatigued and impeding their learning progress.

Table 6: The degrees of importance of criterion

Dimension	Criterion
Teachers 'ethics	c_{11}(0.066), c_{12}(0.069), c_{13}(0.129)
Teaching content	c_{21}(0.023), c_{22}(0.121), c_{22}(0.066), c_{23}(0.059)
Teaching skills	c_{31}(0.108), c_{32}(0.019), c_{33}(0.026), c_{34}(0.024), c_{35}(0.045)
Learning tasks	c_{41}(0.052), c_{42}(0.066)
Teaching effects	c_{51}(0.069), c_{52}(0.058)

The importance values of the criteria related to the "strengthen process teaching, pay attention to cultivating students' learning methods and thinking modes"(c_{34}), "the textbooks are selected appropriately, provide extracurricular reference materials and are effective"(c_{21}), and "seriously organize teaching, teach students according to their aptitude, and moderate the pace of lectures" (c_{32}) are relatively low. However, this does not diminish their significance. Teachers need to meticulously select textbooks and offer relevant extracurricular materials to students. During teaching, educators must continuously enhance the educational process and nurture students' learning strategies to promote active learning. Additionally, teachers should tailor their teaching to students' abilities, carefully plan educational activities beforehand, and adjust the pace of instruction during class to ensure all students can follow along. Hence, educators should strive to enhance the less prioritized indicators to elevate the overall educational quality.

V. CONCLUSIONS

The 202 Fifth Plenary Session of the 19th CPC Central Committee explicitly identified "establishing a high-quality education system" as a crucial strategic mission in the "14th Five-Year Plan" era. It outlined an ambitious vision for achieving educational modernization and creating a robust educational nation by 2035. Developing a robust system for ensuring the quality of higher education teaching is not just a fundamental step in constructing a high-quality education system but also a necessary condition for establishing a formidable higher education nation. Utilizing a genetic algorithm learning method, this study assesses the significance of each criterion based on 462 valid survey responses. A hierarchical framework for assessing teaching quality is established through a combination of literature review and the Delphi method. Triangular fuzzy numbers are employed during questionnaire analysis to capture the uncertainty associated with both overall evaluation and specific teaching quality metrics.

Teaching contentis the primary consideration in factor, with "teacher ethics" and "teaching skills" following closely behind, collectively accounting for nearly 76% of importance. This highlights students' emphasis on these aspects of teaching. Sustaining these dimensions can lead to high student satisfaction and recognition of teachers' efforts in the classroom. Regarding criteria, the most critical factor is the punctuality of "classes start and end on time and do not adjust (stop) classes at will (c_{13})". This is trailed by "the teaching content is practical and can be updated according to the development of the subject (c_{22})" and "vivid teaching, not scripted, proper method(c_{31})". These three indicators sum up to 36%, reflecting students' primary concerns and offering clear guidance for enhancing teaching quality. Conversely, there is less emphasis on factors like "strengthen process teaching, pay attention to cultivating students' learning methods and thinking modes" (c_{34}), "the textbooks are selected appropriately, provide extracurricular reference materials and are effective" (c_{21}), and "seriously organize teaching, teach students according to their aptitude, and moderate the pace of lectures" (c_{32}). This underscores the need for teachers to elevate their teaching standards, which should be their focal point. Ultimately, elevating teaching quality can boost students' motivation and learning outcomes.

In future research, other machine learning methods, such as data mining or neural network, can be used to analyze learning effectiveness factors, which can make decisions more accurate.

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