Multiple-Criteria Decision-Making and Plithogenic Sets-Based TOPSIS Framework for 'Dual-Qualified' Teachers Quality Evaluation in the Context of High-Quality Development of Vocational Education

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Abstract: This study proposed a multi-criteria decision making (MCDM) methodology for evaluating the Dual-Qualified" Teachers Quality. This evaluation has various criteria and factors. So, the MCDM can deal with these factors. This study combines the MCDM methodology with the plithogenic set to deal with uncertainty and vague information. Three experts are invited to evaluate the criteria and alternatives. Then we replace their opinions by using plithogenic numbers. We used plithogenic operators to combine these numbers. Eight criteria and eleven alternatives are used in this study. We used the TOPSIS method under the plithogenic numbers to rank the alternatives. the results show the Professional Knowledge and Industry Expertise criterion has the highest weights and Research and Innovation in Teaching criterion has the lowest weights. We validated the proposed methodology by an application. The results show the proposed methodology is effective.

Keywords: Multiple-Criteria Decision-Making; Dual-Qualified; Vocational Education; TOPSIS Method.

1. Introduction

Higher vocational education's goal, as we all know, is to prepare highly qualified individuals and talented individuals to fill front-line production, construction, management, and service positions in industry businesses. Higher vocational colleges also propose the requirement of "double qualification" for teachers, based on the unique orientation of running a school and the purpose of talent training. Double qualification is the term used to describe the Chinese Ministry of Education's requirement that teachers complete ongoing training through additional coursework and exposure to the industry[1], [2].

This is a crucial component of the talent team in higher vocational colleges; "double-qualified" teachers are the main source of assistance in showcasing the operational features of the school and bolstering the development of talented individuals. The State has released the Execution Plan for Accelerating School Modernization in successive years[3], [4].

Higher vocational education plays a crucial role in China's educational process, and higher standards are proposed for its development in various documents, including "the Implementation Plan for Improving the Quality of Teachers in Vocational Colleges," "the Opinions of the CPC Central Committee and the State Council on Comprehensively Deepening the Reform of the Building of Teachers in the New Era," and Modernization of China's Education[5], [6].

Teachers are crucial to the integration of production, study, research, invention, and application in the modern period. The development of a "Double-qualified" teaching staff is a crucial step in advancing higher vocational education reform and achieving modernization. Vocational colleges must produce competent applied skills in the context of China's social development and industrial upgrading in the new era, and the main assurance is the training of "Double-qualified" teachers[7], [8].

To greatly enhance the quality of talent training and the degree of modernization of China's higher vocational education, support high-tech skilled talent, encourage the social economy's sustainable growth, boost national competitiveness, and assemble a group of "Double-qualified" educators with high moral standards[1], [9].

One of the main issues that decision-makers may encounter in the evaluation process is vagueness and uncertainty. There are several shortcomings in recent studies assessing teacher quality, namely in taking uncertain elements into account that hinder desirable decision-making. Inaccurate conclusions are also produced because the decision maker's priorities and the degree of conflict between factors are not considered[10], [11].

Therefore, the suggested method in this study increased the degree of uncertainty consideration and offered a high degree of accuracy in decision-making situations. By considering the truth-membership function, falsity-membership function, and indeterminacy-membership function, the plithogenic set—a generalization of the neutrosophic set—is more effective in managing ambiguous judgments[12], [13].

The TOPSIS method based integrated plithogenic approach strengthens the consideration of uncertainty and offers a highly reliable and accurate indicator of teacher quality. To address the uncertainty environment, we employ the plithogenic TOPSIS method, which has no other application in the field of teacher quality. This study contributes to the development of a framework evaluation of teacher quality. The suggested method is used to assess the teacher quality[14], [15], [16].

1.1 Objectives

- This paper's primary goal is to assess teacher quality using plithogenic set theory to identify the criteria and alternatives.
- To measure the teacher quality variables, we suggest a combined plithogenic technique based on the TOPSIS method.
- The accuracy of assessments based on decision makers' evaluations is increased by utilizing plithogenic set operations' properties.

1.2 Organization

The rest of the document is structured as follows: Section 2 provides information and definitions regarding the techniques and guiding principles that were employed. Section 3 provides a detailed description of the suggested methodology, including its features and procedures. The use of the suggested method is shown in Section 4, along with a discussion of its outcomes. Section 5 shows the results and discussion. In Section 6, the work's summary is finally provided.

2. Methods

2.1 Plithogenic set

A set that consists of different items defined by several qualities is called a Plithogenic set (P, A, V, d, c). Each attribute has a value V = {v1, v2, …, vn}, with $n \geq 1$. A = {α1, α2, …, αm}, $m \geq 1$. The two primary characteristics that set apart plithogenic sets are the degree of contradiction and the degree of appurtenance. D(x,v) is the appurtenance degree function of element x with regard to the set of specified criteria. Each attribute value is distinguished from the dominant attribute value using the contradiction (dissimilarity) degree function c(v,D). Intersection, union, complement, inclusion, and equality are examples of plithogenic set operations[9], [17].

Let A be a non-empty set of uni-dimensional attributes A = {α1, α2, …, αm}, m ≥ 1, and let α ∈ A be an attribute whose value spectrum is the set S. S can be defined as an infinitely countable set S = {s1, s2, …, s∞}, or as a finite discrete set S = {s1, s2, …, sl}, 1 ≤ l <∞, or as an infinitely uncountable (continuum) set S =]a,b [, a < b, with the range of all attribute values defined by experts depending on the application, V = {v1, v2, …, vn} for n ≥ 1. The decision-maker determines the dominant attribute value in set V, which stands for the most significant value, based on the evaluation and the nature of the issue[18], [19].

2.2 Technique in Order of Preference by similarity to ideal solution (TOPSIS)

TOPSIS is an excellent mathematical MCDM technique that has shown remarkable results in numerous studies and is used to tackle decision-making problems in a variety of fields. This method's primary objective is to determine the best option based on a set of predetermined standards by calculating how far each alternative is from a positive and negative ideal solution. The following is a clear definition of the TOPSIS steps:

1. Step 1: Identify the issue for which you need to determine the best solution given a range of options and the standards by which those options will be evaluated. Next, use the decision matrix to assess each option according to predetermined standards.
2. Step 2: Apply the TOPSIS vector normalization formula to normalize the decision matrix.

$$p_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Where x_{ij} refers to the value in decision matrix.

3. Step 3: Construct the weighted decision matrix as:

$$q_{ij} = w_j \times p_{ij}$$

4. Step 4: Identify the positive and negative ideal solution

$$B^+ = \{q_1^+, \dots, q_n^+\}$$
$$B^+ = \{(\max q_{ij} \,|j \in J_b), (\min q_{ij} \,|j \in J_b)| \ \in [1 \dots m]\}$$
$$B^- = \{q_1^-, \dots, q_n^-\}$$
$$B^- = \{(\min q_{ij} \,|j \in J_b), (\max q_{ij} \,|j \in J_b)| \ \in [1 \dots m]\}$$

5. Step 5: Compute the distance of every alternative using the Euclidean distance as:

$$D_i^+ = \left[\sum_{j=1}^{m} \left(B_i - B_j^+\right)^2\right]^{\frac{1}{2}}$$

$$D_i^- = \left[\sum_{j=1}^{m} \left(B_i - B_j^-\right)^2\right]^{\frac{1}{2}}$$

6. Step 6: Compute the closeness coefficient of every alternative.

$$R_i = \frac{D_i^-}{D_i^+ - D_i^-}$$

7. Step 7: Rank the alternatives

3. Proposed Approach

To assess sustainable Teachers Quality, we present a plithogenic TOPSIS technique in this study. This approach's significance stems from its high degree of uncertainty consideration and enhanced evaluation process accuracy. Features of plithogenic set aggregation, like the contradiction degree function, guarantee more precise conclusions that surpass those of other researchers at the same time. To choose the optimum course of action, TOPSIS primarily focuses on evaluating the set of criteria by contrasting the options with the best and worst solutions. Based on the criteria's conflict nature and degree of difference, we determine the objective weight. This method creates a robust model by combining the benefits of the TOPSIS, and plithogenic aggregation operator. Figure 1 shows the steps of the proposed methodology.

- Step 1: Determine committee of experts to help in the evaluation process in the MCDM methodology. Set of experts as $D = \{D_1, \dots, D_k\}$, criteria $C = \{C_1, \dots, C_n\}$, and alternatives $A = \{A_1, \dots, A_m\}$.
- Step 2. Establish the language scale that DMs will use to assess the criteria and options. This method defines the plithogenic numbers. DMs assess the specified set of criteria and options using this scale.
- Step 3. Build the combination of decision matrix. Then compute the crisp values.
- Step 4. Compute the criteria weights by normalizing the crisp values.
- Step 5. Apply the steps of the TOPSIS method under the plithogenic.
- Step 6. Normalize the decision matrix.
- Step 7. Build the weighted normalized decision matrix.

- Step 8. Find the distance of every alternative from positive and negative ideal solution.
- Step 9. Compute the closeness coefficient.
- Rank the alternatives.

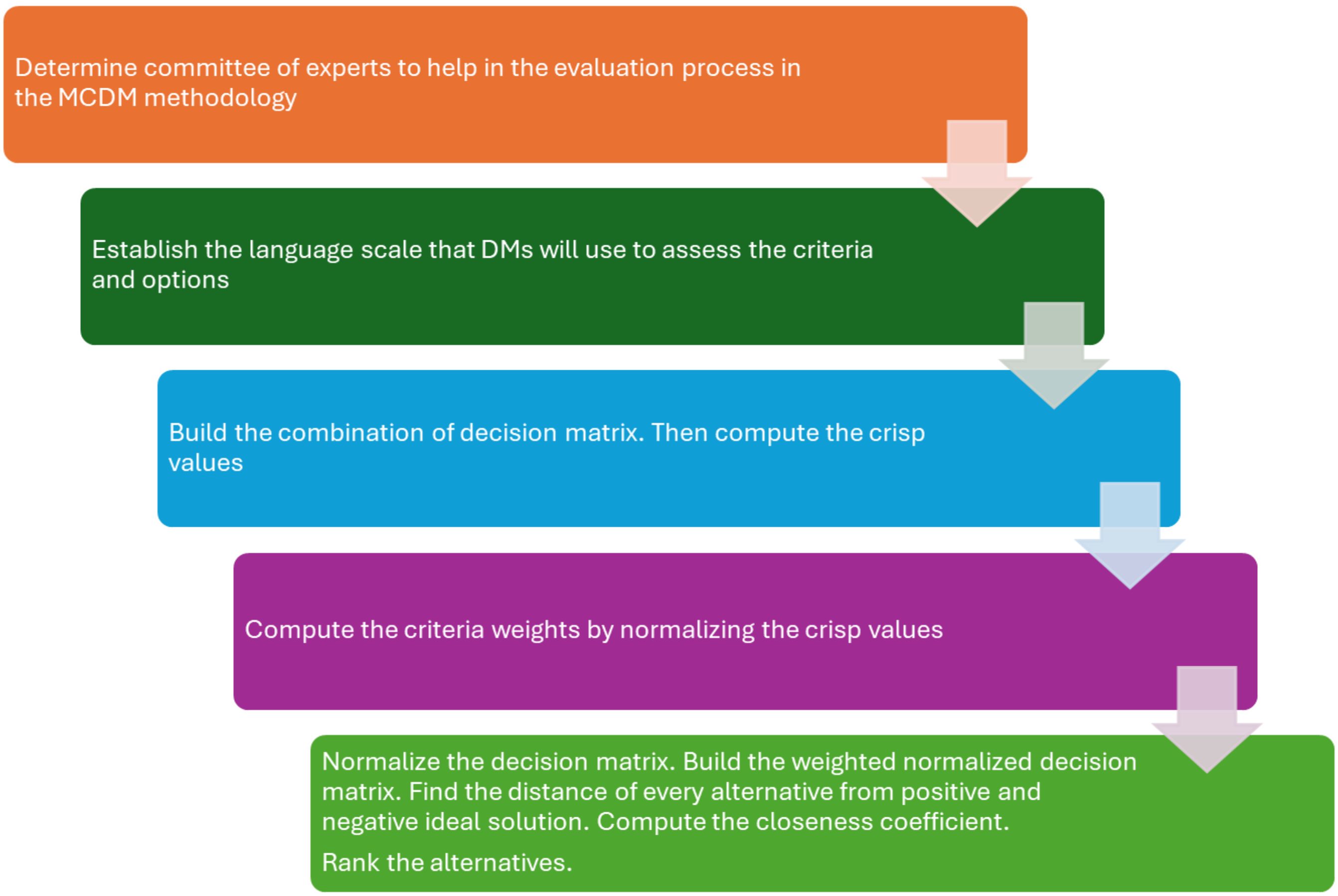

Figure 1. Steps of the proposed model.

4. Application of proposed approach and discussion

This section shows the criteria and alternatives used in this study. Three experts collected eight criteria and eleven alternatives as shown in Figure 2. Three experts have experience in field of teacher quality.

Figure 2. Aspects of evaluation of this study.

Table 1. Judgment of experts.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)
A_2	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)
A_3	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)
A_4	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)
A_5	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)
A_6	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)
A_7	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)
A_8	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)
A_9	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)
A_{10}	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)
A_{11}	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)

Table 2. Judgment of experts.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)
A_2	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)
A_3	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
A_4	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)
A_5	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)
A_6	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)
A_7	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)
A_8	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)
A_9	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)

A10	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)
A11	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)

Table 3. Judgment of experts

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)
A2	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
A3	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)
A4	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)
A5	(0.25, 0.60, 0.80)	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
A6	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)
A7	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
A8	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A9	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
A10	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.80, 0.10, 0.30)
A11	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)

5. Results and Discussion

Applying the proposed model on application of eight criteria eleven alternatives in this study as following:

- ❖ The objective of this study is determining criteria and alternatives.
- ❖ Three decision makers evaluate the criteria and alternatives as shown in Tables 1-3.
- ❖ We combine the decision matrix with the plithogenic operators.
- ❖ We convert the plithogenic numbers into crisp values.
- ❖ Then we normalize the crips values to compute the criteria weights as shown in Figure 3.

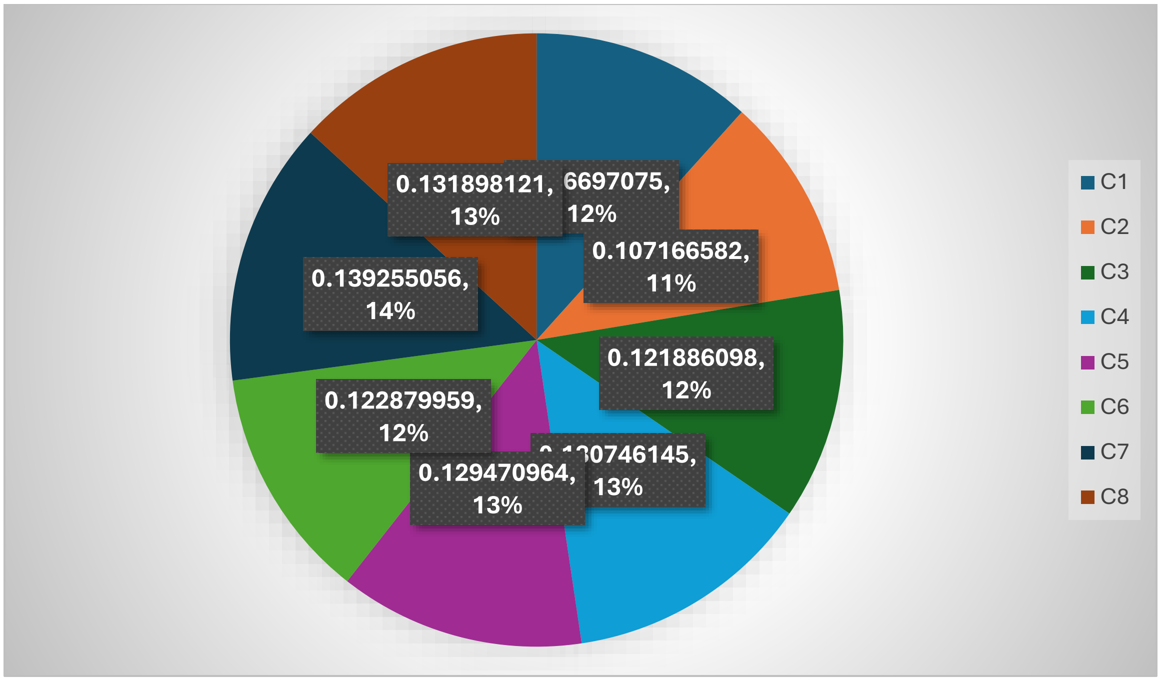

Figure 3. The criteria weights.

- ❖ We applied the steps of the TOPSIS method to rank the alternatives. We normalize the decision matrix as shown in Table 4.
- ❖ We compute the weighted normalized decision matrix as shown in Table 5.
- ❖ Then we compute the distance of every alternative from positive and negative ideal solution.
- ❖ Then we compute the closeness values as shown in Table 6.
- ❖ Then we rank the alternatives.

Table 4. The normalization matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.289932624	0.128771	0.283297	0.226486	0.255382	0.299311	0.297757	0.34313
A_2	0.371820062	0.248181	0.268702	0.35278	0.394396	0.27096	0.337874	0.28229
A_3	0.344631861	0.215666	0.328476	0.322738	0.164622	0.406347	0.213534	0.282466
A_4	0.265621852	0.456793	0.383795	0.317615	0.312282	0.210528	0.315208	0.162682
A_5	0.275419149	0.336469	0.211403	0.296249	0.164622	0.413248	0.279118	0.359101
A_6	0.364830013	0.283421	0.344275	0.340964	0.363384	0.120945	0.369877	0.237784
A_7	0.359622568	0.407699	0.276341	0.211889	0.24062	0.214231	0.297757	0.25633
A_8	0.254112133	0.336469	0.317011	0.283789	0.259388	0.275517	0.272618	0.221097
A_9	0.286339346	0.363307	0.378631	0.311437	0.326421	0.293742	0.276498	0.304027
A_{10}	0.31553473	0.191284	0.324529	0.352471	0.377485	0.341345	0.3122	0.389747
A_{11}	0.06286833	0.15844	0.059921	0.261779	0.34819	0.34285	0.317197	0.389747

Table 5. The weighted normalized matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.033834289	0.0138	0.03453	0.029612	0.033065	0.036779	0.041464	0.045258
A_2	0.043390314	0.026597	0.032751	0.046125	0.051063	0.033296	0.047051	0.037233
A_3	0.04021753	0.023112	0.040037	0.042197	0.021314	0.049932	0.029736	0.037257
A_4	0.030997293	0.048953	0.046779	0.041527	0.040431	0.02587	0.043894	0.021457
A_5	0.032140609	0.036058	0.025767	0.038733	0.021314	0.05078	0.038869	0.047365
A_6	0.042574595	0.030373	0.041962	0.04458	0.047048	0.014862	0.051507	0.031363
A_7	0.041966902	0.043692	0.033682	0.027704	0.031153	0.026325	0.041464	0.033809
A_8	0.029654143	0.036058	0.038639	0.037104	0.033583	0.033855	0.037963	0.029162
A_9	0.033414964	0.038934	0.04615	0.040719	0.042262	0.036095	0.038504	0.040101
A_{10}	0.03682198	0.020499	0.039556	0.046084	0.048873	0.041944	0.043475	0.051407
A_{11}	0.00733655	0.016979	0.007304	0.034227	0.04508	0.042129	0.044171	0.051407

Table 6. The rank of alternatives.

	Closeness values	Rank
A_1	0.049075257	10
A_2	0.034972031	3
A_3	0.047944297	9
A_4	0.043164864	6
A_5	0.043012262	5
A_6	0.04560096	8
A_7	0.044108413	7
A_8	0.042104851	4
A_9	0.02862716	1
A_{10}	0.032439267	2
A_{11}	0.064703217	11

6. Conclusions

This study proposed a MCDM methodology to evaluate the teacher quality. We used the TOPSIS method to rank the alternatives. The TOPSIS method is integrated with the plithogenic number to deal with vague and uncertainty information. Eight criteria and eleven alternatives are gathered from previous studies. These data are evaluated by the three experts. We compute the criteria weights and rank the alternatives. We used plithogenic operators to combine the plithogenic numbers into single matrix. We compute the closeness value to rank the alternatives. The alternatives are ranked based on the highest value in the closeness values. The results show alternative 11 is the best and alternative 9 is the worst.

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