Application of Triangular Fuzzy Analytic Hierarchy Process in Combination with Normal Function in MOOC Evaluation

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Abstract

In this study, a three-level fuzzy comprehensive MOOC quality evaluation model based on the triangular fuzzy analytic hierarchy process (AHP) was constructed, aiming to improve MOOC quality. In this model, AHP was improved by introducing the theory of triangular fuzzy number. Next, the triangular fuzzy AHP was adopted to determine the index weight at each layer, which overcame the strong expert subjectivity in assigning values and the poor consistency of judgment matrices. Moreover, normally distributed membership functions were used to determine the degree of membership for each factor, thus contributing to the more reasonable and reliable single-factor evaluation and the more accurate final evaluation results. Thereby, the overwhelming problem of single-factor information resulting from excessive factors was solved through a three-level comprehensive evaluation. In addition, the modeling method was expounded with the navigation specialty in higher vocational schools as an example. Finally, its scientificity, reasonability, and practicability were verified through an example.

Keywords: *Normally distributed membership function, triangular fuzzy analytic hierarchy process, fuzzy comprehensive evaluation*

1 INTRODUCTION

Since 2012, MOOC, a new education model rich in “sense of experience” with strong “fragmentation” and “interactivity”, has attracted a lot of learners. Through decades of development, however, MOOC has encountered bottlenecks, *i.e.*, “weak learning continuity” and “high drop-out rate” that are hard to overcome. According to statistics, the drop-out rate from MOOC has reached as high as 80-95% in international famous universities like Stanford University and Massachusetts Institute of Technology, and that in UOOC of colleges and universities in China has also reached 96%, fully proving that MOOC quality has seriously impacted learning interests. Hence, it is now urgent for institutions of higher learning and competent education departments to establish an appropriate MOOC quality evaluation system and construct a scientific and reasonable evaluation model to improve MOOC quality and stimulate learning interests.

2 LITERATURE REVIEW

Through literature retrieval, it has been found that all research results regarding quality evaluation develop on basis of online courses and excellent course quality evaluation, where experimental method, observation method, analytical approach, and index system evaluation method have been mainly adopted . The index system evaluation method has been recently investigated by many scholars because of its good objectivity and easy operation. When using the index system evaluation method, some scholars attach importance to the construction of evaluation index systems. For instance, (Chen 2019) [1] constructed a teaching quality evaluation index system combining traditional teaching, MOOC, and SPOC. In addition, attention has also been paid to determining index weights at each layer. For example, (Tang, Jia 2017) [5] established a MOOC quality evaluation index system combining various factors by reference to the evaluation criteria for online sources, and determined index weights with the analytic hierarchy process (AHP). (Zhang, Liu 2019) [9] established a MOOC quality evaluation system with distinct layers and

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a clear structure, and calculated the weight of each index via MATLAB. Not stopping at the above mentioned studies, index systems have been evaluated by scholars by introducing mathematical fuzzy comprehensive evaluation models. (Qiu 2015) [2] and (Li 2016) [3] established a three-layer MOOC quality evaluation index system, determined the index weight at each layer through AHP, and then comprehensively evaluated MOOC quality with a fuzzy comprehensive evaluation model. (Li 2016) [4] improved the method adopted by teacher Jia jun Li to determine index weights, and introduced the concept of voting weight of the judging panel, making the fuzzy comprehensive evaluation more accurate and practical. (Zhao 2017) [10] constructed a quality evaluation index system for College Physics MOOC, and comprehensively evaluated College Physics MOOC in three universities using the fuzzy comprehensive evaluation method. Moreover, all kinds of comprehensive evaluation models have been constructed by reference to the comprehensive evaluation methods in the engineering field. (Yao 2017) [7] used AHP to establish a MOOC quality evaluation index system, and construct an evaluation model through the similarity measurement method of Vague sets. (Xiao 2022) [6] set up learning behavior evaluation indexes, and constructed an evaluation model of students' learning behavioral state using the hidden Markov method and data mining technology. (Yue 2019) [8] designed a multilayer MOOC applicability evaluation index system, and established a MOOC applicability evaluation model using the group decision method based on the theory of interval number.

To sum up, an evaluation index system is generally established at first when the index system evaluation method is adopted. Then, index weights are calculated using AHP, followed by evaluation with all kinds of evaluation models to obtain a quantified evaluation result. However, the depth and breadth of research are still insufficient. When measuring the importance of two indexes, expert differences in knowledge, life experience, and working experience are not considered in AHP, and thus the values assigned by experts are too absolute. In addition, the degree of membership is not objectively enough determined due to the inappropriate processing of qualitative factors during the construction of a fuzzy evaluation matrix, all of which will greatly impact the scientificity and reasonability of evaluation results.

Given this, a three-level fuzzy comprehensive MOOC quality evaluation model based on triangular fuzzy AHP was established. Next, AHP was improved by introducing the fuzzy mathematic theory, and then index weights were determined through the triangular fuzzy AHP. Relative to AHP, the triangular fuzzy AHP not only fully considered the fuzziness of expert value assignment but also saved the consistency check of judgment matrices, so the determined weights were more scientific and reasonable. Then, all qualitative factors were quantitatively scored by an expert committee, followed by interpolation calculation of normally distributed membership functions, which fully embodied indeterminacy and fuzziness and led to a more objective and reasonable degree of membership determined. Only in this way can the application results of the above improved three-level fuzzy MOOC quality evaluation model be more scientific, reasonable, and objective.

3 CONSTRUCTION OF A MOOC QUALITY EVALUATION MODEL BASED ON TRIANGULAR FUZZY AHP

Here, the model construction method was expounded with MOOC quality evaluation of the navigation specialty in higher vocational schools as an example.

3.1 To Establish a MOOC Quality Evaluation Index System for The Navigation Specialty in Higher Vocational Schools

A scientific and reasonable evaluation index system is the foundation for evaluation research. The selection of evaluation indexes and the system construction constitute a rigorous and continuous improvement process. To be specific, the construction principle of the evaluation index system and the cultivation goals of the navigation specialty should be abided by. Moreover, domestic, and foreign outstanding research results regarding MOOC quality and the construction methods for other professional evaluation index systems should be referenced. In addition, field surveys should be combined, finally targeting a scientific, reasonable, and highly operable MOOC quality evaluation index system.

Therefore, preliminary indexes were firstly selected through a questionnaire survey and expert interview, and then corrected by the Delta method. Finally, a MOOC quality evaluation index system (Table 1) for the navigation specialty in higher vocational schools was established.

Table 1: MOOC quality evaluation index system for navigation specialty in higher vocational schools.

General Objectives	First-level indexes	Second-level indexes	Third-level indexes
A quality evaluation index system for MOOC-based maritime-related vocational education (U)	Teaching Resources (U_1)	Course Resources (U_{11})	Novelty (U_{111})
			Practicality (U_{112})
			Completeness (U_{113})
		Teaching Team (U_{12})	Providing organization (U_{121})
			Host (U_{122})
			Teaching Team (U_{123})
		Instructional Design (U_{13})	Teaching Objectives (U_{131})
			Teaching Methods (U_{132})
			Teaching content (U_{133})
			Learning tasks (U_{134})
		Teaching activities (U_{14})	Project Analysis (U_{141})
			Interaction (U_{142})
			Student-student Collaboration (U_{143})
		Teaching Evaluation(U_{15})	Evaluation subject (U_{151})
			Evaluation Method (U_{152})
			Feedback (U_{153})
	Learning Experience (U_2)	Emotions (U_{21})	like or dislike (U_{211})
			Sense of presence(U_{212})
			Satisfaction (U_{213})
		Intrinsic Value (U_{22})	Self-interest (U_{221})
			Self-efficacy (U_{222})
			Deep Thinking (U_{223})
		Forming Values (U_{23})	Skill level (U_{231})
		External utility value(U_{24})	Solving real problems (U_{241})
	Course Platform (U_3)	Page design (U_{31})	Page layout (U_{311})
			Guide for learning (U_{312})
			Color assortment (U_{313})
		Functions of the platform (U_{32})	Basic functions (U_{321})
			Featured functions (U_{322})

This index system realized the comprehensive evaluation of MOOC quality from three aspects: teacher, student, and platform. The indexes selected fully covered school attributes, professional characteristics, and students' emotional attitudes.

3.2 *Determine Factor Set and Weight Set*

The indexes at each layer of the MOOC quality evaluation index system for the navigation specialty in higher vocational schools were selected as the factor set, as follows: U= { U_1,U_2,U_3 } , U_1= {$U_{11},U_{12},U_{13},U_{14},U_{15}$} , U_2= {$U_{21},U_{22},U_{23},U_{24}$} , U_3= { U_{31},U_{32} } , U_{11}= { U_{111},U_{112},U_{113} } , U_{12}= {U_{121},U_{122},U_{123}} , U_{13}= {$U_{131},U_{132},U_{133},U_{134}$} , U_{14}= { U_{141},U_{142},U_{143} } , U_{15}= { U_{151},U_{152},U_{153} } , U_{21}= { U_{221},U_{222},U_{223} } , U_{22}= { U_{221},U_{222},U_{223} } , U_{23}= {U_{231}} , U_{24}= {U_{241}} , U_{31}= {U_{311},U_{312},U_{313}} , U_{32}= {U_{321},U_{322}} .

According to the international practice, an evaluation set Z= { Z1(excellent), Z2(good), Z3(medium), Z4(qualified), Z5(to be improved) was established using the five-level evaluation principle.

3.3 To Determine Index Weights

The traditional AHP does not consider expert differences in knowledge, life experience, and working experience, which is its greatest disadvantage. Moreover, the comparison process is too absolute, while the uniqueness of relative importance between factors is stressed. In this study, AHP was improved by introducing the fuzzy mathematic theory, and index weights were calculated through the triangular fuzzy AHP, which took full consideration of the fuzziness of expert value assignment in comparison with the traditional AHP.

3.3.1 To Establish a Fuzzy Judgment Matrix

MOOC evaluation experts were invited to make comparisons between every two of n indexes at *k* layers and assign values through triangular fuzzy numbers. When experts gave $n(n-1)/2$ fuzzy judgments, a fuzzy judgment matrix $A^k=(a_{ij}^k)_{n\times n}$ could be established with triangular fuzzy numbers as elements,where $a_{ij}^k=(l_{ij},m_{ij},u_{ij})$,*i,j=1,2,3...n*, and l_{ij}, m_{ij} and u_{ij} stand for the pessimistic value, possible value, and optimistic value of triangular fuzzy numbers. The fuzzy evaluation results obtained by multiple experts could be averaged through the operation rule [Equation (1)] of triangular fuzzy numbers as a comprehensive triangular fuzzy number.

$$M_i\oplus M_j=(l_i+l_j,m_i+m_j,u_i+u_j) \quad (1)$$

$$M_i\otimes M_j=(l_i\times l_j,m_i\times m_j,u_i\times u_j) \quad (2)$$

$$kM_i=(kl_i,km_i,ku_i) \quad (3)$$

$$\frac{1}{M_i}=(\frac{1}{u_i},\frac{1}{m_i},\frac{1}{l_i}) \quad (4)$$

Where $M_i=(l_i,m_i,u_i)$ and $M_j=(l_j,m_j,u_j)$.

3.3.2 To Calculate Index Weights at Each Layer

First, the following could be acquired according to the theorem of triangular fuzzy number:

$$D_i^k=\sum_{j=1}^{n}a_{ij}^k\div(\sum_{i=1}^{n}\sum_{j=1}^{n}a_{ij}^k) \quad (5)$$

where *i,j=1,2,3..n*. The comprehensive fuzzy weight D_i^k of the index *i* at layer *k* was calculated. Similarly, the comprehensive fuzzy weight D_j^k of the index *j* at the same layer could also be solved. Thereby, the following could be solved through the theorem of triangular fuzzy number:

$$V(M_i\ge M_j)=\begin{cases}1 & m_i\ge m_j\\ \dfrac{l_j-u_i}{(m_i-u_i)-(m_j-l_j)} & m_i<m_j,u_i\ge l_j\\ 0 & \text{其它}\end{cases} \quad (6)$$

The probability of $D_i^k\ge D_j^k$ was calculated. Then, the following could be acquired based on the theorem of triangular fuzzy number:

$$d_i^k=\min V\left(D_i^k\ge D_j^k\right),i\ne j \quad (7)$$

The weight of a triangular fuzzy number was transformed into the weight of a real number and then normalized to obtain the index weight W^k at layer *k*.

3.4 To Establish a Membership Function and Determine the Degree of Membership

In engineering practice and scientific research, whether a factor belongs to one level, two absolute conclusions, 0 or 1, are generally given, but the degree of membership of each evaluation factor to one level is usually fuzzy, which, however, is effectively solved by fuzzy mathematics. The degree of membership is believed to be full of continuity intervals: {0,1} →[0,1]. Most factors influencing MOOC quality evaluation for the navigation specialty in higher vocational schools were qualitative factors. For qualitative factors, the corresponding score interval for each level was divided, based on which the membership function in each interval was determined. Moreover, the concrete quantitative values of factors were given by experts, followed by interpolation calculation. Given the certain subjectivity and differences of expert opinions, the invited experts consisted of MOOC evaluation experts, MOOC developers, and student representatives, which guaranteed the reasonability of scoring results. The division rules for the score interval at each level are listed in Table 2.

Table 2: Division rules for the score interval at Each level.

Evaluation level	Excellent	Good	Medium	Qualified	To be improved
Quantified value	100-90	90-80	80-70	70-60	60-0

It is very crucial to determine the membership function. When the quantified value given by experts was closer to the interval midpoint, the degree of membership to this level was higher. The greater closeness to the interval edge indicated a lower degree of membership, and it might belong to another level. Hence, a normally distributed function was chosen as the interval membership function, as below:

$$\mu(x) = \exp^{-\left(\frac{x-x_0}{\sigma}\right)^2} \quad (8)$$

Where x represents the score given by experts, and x_0 stands for the midpoint of the score interval at each level, namely, $x_0=(x_1+x_2)/2$. Obviously, the degree of membership of $x=x_0$ was 1, the quantified evaluation value was located at the interval endpoint, reaching the highest fuzziness level, so it was difficult to judge to which level it belonged, and then the degree of membership to the adjacent interval was 0.5, namely:

$\mu(x) = \exp^{-\left(\frac{x_1-x_0}{\sigma}\right)^2} = \exp^{-\left(\frac{x_1-x_2}{2\sigma}\right)^2} = 0.5$, where x_1 and x_2 stand for interval endpoint. $\sigma=(x_1-x_2)/1.66$ was solved. With Table 2 combined, the reference value of the membership function within each interval could be solved, as seen in Table 3.

Table 3: Reference value of membership function.

Excellent		Good		Medium		Qualified		To be improved	
x_{01}	σ_1	x_{02}	σ_2	x_{03}	σ_3	x_{04}	σ_4	x_{05}	σ_5
95	6.02	85	6.02	75	6.02	65	6.02	30	36.14

When the normally distributed membership function was used, the closer the quantified value to the interval midpoint, the higher the degree of membership, and on the contrary, the closer it was to the interval endpoint, the lower the degree of membership. The situations for intervals [100,90] and [60,0] at two ends were different, the degree of membership should be higher (yet not exceeding 1) when the quantified value was closer to 100 or 0. If the only normal distribution was adopted, the degree of membership would be lower than 1, which was out of line with the real situation, so it was necessary to correct the membership function of intervals at two ends, as follows:

$$\mu_1(x) = \begin{cases} 1, & 95 < x \le 100 \\ \exp^{-\left(\frac{x-x_{01}}{\sigma_1}\right)^2}, & 0 < x \le 95 \end{cases} \quad (9)$$

$$\mu_2(x) = \exp^{-\left(\frac{x-x_{02}}{\sigma_2}\right)^2} \quad (10)$$

$$\mu_3(x) = \exp^{-\left(\frac{x-x_{03}}{\sigma_3}\right)^2} \quad (11)$$

$$\mu_4(x) = \exp^{-\left(\frac{x-x_{04}}{\sigma_4}\right)^2} \quad (12)$$

$$\mu_5(x) = \begin{cases} \exp^{\left(\frac{x-x_{05}}{\sigma_5}\right)^2}, & 30 \le x \\ 1, & 0 \le x < 30 \end{cases} \quad (13)$$

To sum up, the degree of membership was calculated according to Equations (9-13) after score values were given by experts. Then, the membership matrix row R was established. In this study, it was only necessary to establish the membership matrix row for the third-level indexes.

3.5 *Comprehensive Evaluation*

After the weights (W^k) of all indexes at layer k were solved and the membership matrix row R^k at this layer was established, $S^k = W^k \otimes R^k$ was solved according to the multiplication rule of the matrix, thus obtaining the evaluation result of the index k. The calculation proceeded upward layer by layer until acquiring the final result S. Next, the column with the maximum degree of membership in S was selected as the final evaluation result.

4 APPLICATION TO A REAL EXAMPLE

Here, the course Main Propel Power Unit of the navigation specialty constructed by the in-service education smart platform of Wuhan Institute of Shipbuilding Technology was taken for example to verify the scientificity, reasonability, and practicability of the MOOC evaluation model for the navigation specialty in higher vocational schools based on the triangular fuzzy AHP.

4.1 Calculate Index Weights at Each Level

The calculation process of index weights at all levels was expounded with the "novelty, practicability, and integrity" of the three-level indexes as examples. First, three MOOC evaluation experts were invited to evaluate the importance of the above indexes. Then, a fuzzy judgment matrix was constructed. Next, the comprehensive fuzzy judgment matrix was calculated through Equations (1) and (3), as seen in Table 4:

Table 4: Comprehensive fuzzy judgment matrix for "novelty, practicability, and integrity" of three-level indexes.

U_{11}	U_{111}	U_{112}	U_{113}
U_{111}	(1,1,1)	(0.28 , 0.39,0.83)	(0.83,1.67,3)
U_{112}	(1.33,2.67,3.67)	(1,1,1)	(2.33,3.67,4.67)
U_{113}	(0.36,0.67,1.33)	(0.22,0.28,0.43)	(1,1,1)

The fuzzy comprehensive weights of the above indexes were calculated according to Equation (5), as below:

$$\sum_{j=1}^{3} a_{1j}^3 = (2.11,3.06,4.83)$$

$$\sum_{i=1}^{3}\sum_{j=1}^{3} a_{ij}^3 = (8.35,12.35,16.93)$$

$$D_{U_{111}}^3 = \sum_{j=1}^{3} a_{1j}^3 \div \sum_{i=1}^{3}\sum_{j=1}^{3} a_{ij}^3 = (0.12,0.25,0.58)$$

Similarly, $D_{U_{112}}^3 = (0.28,0.59,1.12)$

$D_{U_{113}}^3 = (0.09,0.16,0.33)$ could be solved. The probability of $D_{U_{11i}}^3 \geq D_{U_{11j}}^3$ was calculated as per Equation (6), where *i,j* =1, 2, 3, respectively being

$$V\ (D_{U_{111}}^3 \geq D_{U_{112}}^3) = 0.47$$

$$V\ (D_{U_{111}}^3 \geq D_{U_{113}}^3) = 1$$

$$V\ (D_{U_{112}}^3 \geq D_{U_{111}}^3) = 1$$

$$V\ (D_{U_{112}}^3 \geq D_{U_{113}}^3) = 1$$

$$V\ (D_{U_{113}}^3 \geq D_{U_{111}}^3) = 0.7 \text{ and } V\ (D_{U_{113}}^3 \geq D_{U_{112}}^3) = 0.1$$

Furthermore, the triangular fuzzy weight was converted into the real number weight through Equation (7), as follows:

$$d_{u_{111}}^3 = \min\left[V(D_{U_{111}}^3 \geq D_{U_{112}}^3), V(D_{U_{111}}^3 \geq D_{U_{113}}^3)\right] = 0.47$$

$$d_{u_{112}}^3 = \min\left[V(D_{U_{112}}^3 \geq D_{U_{111}}^3), V(D_{U_{112}}^3 \geq D_{U_{113}}^3)\right] = 1$$

$$d_{u_{113}}^3 = \min\left[V(D_{U_{113}}^3 \geq D_{U_{111}}^3), V(D_{U_{113}}^3 \geq D_{U_{112}}^3)\right] = 0.1$$

The real number weight vector could be obtained as $\overline{W_{U_{11}}} =$ (0.47, 1, 0.1) and normalized into $W_{U_{11}} =$ (0.30, 0.63, 0.07). In a similar way, the index weight at other levels could be solved (Table 5):

Table 5: Index Weight at Each Level.

First-level index	Weight	Second-level index	Weight	Third-level index	Weight
U_1	0.25	U_{11}	0.09	U_{111}	0.30
				U_{112}	0.63
				U_{113}	0.07
		U_{12}	0.21	U_{121}	0.35
				U_{122}	0.48

				U_{123}	0.17
		U_{13}	0.36	U_{131}	0.18
				U_{132}	0.31
				U_{133}	0.37
				U_{134}	0.14
		U_{14}	0.24	U_{141}	0.17
				U_{142}	0.43
				U_{143}	0.40
		U_{15}	0.10	U_{151}	0.27
				U_{152}	0.41
				U_{153}	0.32
U_2	0.60	U_{21}	0.16	U_{211}	0.38
				U_{212}	0.19
				U_{213}	0.43
		U_{22}	0.48	U_{221}	0.39
				U_{222}	0.38
				U_{223}	0.23
		U_{23}	0.24	U_{231}	1.00
		U_{24}	0.12	U_{241}	1.00
U_3	0.15	U_{31}	0.34	U_{311}	0.40
				U_{312}	0.43
				U_{313}	0.17
		U_{32}	0.66	U_{321}	0.67
				U_{322}	0.33

4.2 Determine the degree of membership for third-level indexes

The determination method for the degree of membership of the third-level indexes was expounded still with the "novelty, practicability, and integrity" of the third-level indexes as examples, among which "novelty" was a qualitative index. First, the quantified values of "novelty" were given by three evaluation experts and then averaged. Next, the degree of membership of this index to each level was calculated through Equations (9-13). For example, "novelty" was scored by experts as 77, namely x=75, and its degree of membership to the level "medium" is as below:

$$\mu_3(x) = \exp^{-\left(\frac{x-x_{03}}{\sigma_3}\right)^2} = \exp^{-\left(\frac{77-75}{6.02}\right)^2} = 0.89$$

Similarly, the degree of membership of this index to other levels was calculated, and finally, a degree of membership subset was established and normalized. Through the above method, the degree of membership of all the third-level indexes could be calculated to establish their respective degree of membership subsets and further construct a degree of membership matrix row (Table 6).

Table 6: Degree of Membership Matrix Row of Third-Level Indexes.

Third-level index	Excellent	Good	Medium	Qualified	To be improved
U_{111}	0.22	0.24	0.34	0.16	0.04
U_{112}	0.38	0.32	0.18	0.12	0
U_{113}	0.16	0.18	0.36	0.18	0.12
U_{121}	0.46	0.28	0.16	0.10	0

U_{122}	0.16	0.24	0.28	0.22	0.1
U_{123}	0.30	0.33	0.21	0.10	0.06
U_{131}	0.20	0.30	0.22	0.16	0.12
U_{132}	0.21	0.26	0.33	0.14	0.06
U_{133}	0.12	0.26	0.34	0.12	0.16
U_{134}	0.14	0.28	0.26	0.22	0.10
U_{141}	0.18	0.23	0.30	0.26	0.03
U_{142}	0.16	0.18	0.32	0.28	0.06
U_{143}	0.12	0.19	0.28	0.32	0.09
U_{151}	0.44	0.32	0.24	0	0
U_{152}	0.38	0.30	0.21	0.11	0
U_{153}	0.21	0.36	0.20	0.18	0.05
U_{211}	0.10	0.22	0.35	0.20	0.13
U_{212}	0.18	0.26	0.38	0.16	0.02
U_{213}	0.28	0.31	0.22	0.14	0.05
U_{221}	0.22	0.28	0.30	0.16	0.04
U_{222}	0.16	0.24	0.33	0.20	0.07
U_{223}	0.12	0.28	0.38	0.16	0.06
U_{231}	0.42	0.31	0.22	0.05	0
U_{241}	0.28	0.32	0.30	0.10	0
U_{311}	0.34	0.26	0.22	0.10	0.08
U_{312}	0.38	0.29	0.20	0.13	0
U313	0.25	0.29	0.31	0.15	0
U_{321}	0.48	0.32	0.20	0	0
U_{322}	0.18	0.27	0.35	0.15	0.05

4.3 Comprehensive Evaluation

Since the MOOC quality evaluation system for the navigation specialty in higher vocational schools, the evaluation started from the third-level indexes and proceeded upward until reaching the final result. Here, the first-level fuzzy comprehensive evaluation method was expounded with the "novelty, practicability, and integrity" of the third-level indexes as examples.

4.3.1 First-level Fuzzy Comprehensive Evaluation

The above index weight $W_{u_{11}} = [0.30 \quad 0.63 \quad 0.07]$ was extracted from Table 6, and the degree of membership from Table 6 to construct a degree of membership matrix row.

$$R_{u_{11}} = \begin{bmatrix} 0.22 & 0.24 & 0.34 & 0.16 & 0.04 \\ 0.38 & 0.32 & 0.18 & 0.12 & 0 \\ 0.16 & 0.18 & 0.36 & 0.18 & 0.12 \end{bmatrix},$$

$S_{u_{11}} = W_{u_{11}} \otimes R_{u_{11}} = [0.32 \quad 0.27 \quad 0.24 \quad 0.14 \quad 0.03]$ was solved according to the multiplication of the matrix, and $S_{u_{11}}$ was named the evaluation result of the above indexes, *i.e.*, the degree of membership of the second-level index "course resource". The evaluation results of other third-level indexes could be solved in a similar fashion.

4.3.2 Second-level Fuzzy Comprehensive Evaluation

The degree of membership matrix row was constructed for the second-level indexes:

$$R_{u_1} = \begin{bmatrix} S_{u_{11}} \\ S_{u_{12}} \\ S_{u_{13}} \\ S_{u_{14}} \\ S_{u_{15}} \end{bmatrix} = \begin{bmatrix} 032 & 0.27 & 0.24 & 0.14 & 0.03 \\ 0.29 & 0.27 & 0.23 & 0.16 & 0.05 \\ 0.17 & 0.27 & 0.30 & 0.15 & 0.11 \\ 0.15 & 0.19 & 0.30 & 0.29 & 0.07 \\ 0.34 & 0.32 & 0.21 & 0.10 & 0.03 \end{bmatrix}$$

$$R_{u_2}=\begin{bmatrix}S_{u_{21}}\\S_{u_{22}}\\S_{u_{23}}\\S_{u_{24}}\end{bmatrix}=\begin{bmatrix}0.19 & 0.27 & 0.30 & 0.17 & 0.07\\0.17 & 0.26 & 0.33 & 0.17 & 0.07\\0.42 & 0.31 & 0.22 & 0.05 & 0\\0.28 & 0.32 & 0.30 & 0.10 & 0\end{bmatrix}$$

$$R_{u_3}=\begin{bmatrix}S_{u_{31}}\\S_{u_{32}}\end{bmatrix}=\begin{bmatrix}0.34 & 0.28 & 0.23 & 0.12 & 0.03\\0.38 & 0.30 & 0.25 & 0.05 & 0.02\end{bmatrix}$$

The weights of the second-level indexes were extracted from Table 5.

$$W_{u_1}=[0.09\ \ 0.21\ \ 0.36\ \ 0.24\ \ 0.10]$$

$$W_{u_2}=[0.16\ \ 0.48\ \ 0.24\ \ 0.12]$$

$$W_{u_3}=[0.34\ \ 0.66].$$

According to the multiplication of the matrices, the evaluation results of the second-level indexes were respectively solved as

$$S_{u_1}=W_{u_1}\otimes R_{u_1}=[0.22\ \ 0.26\ \ 0.27\ \ 0.18\ \ 0.07]$$

$S_{u_2}=[0.25\ \ 0.28\ \ 0.30\ \ 0.13\ \ 0.04]$ and $S_{u_3}=[0.37\ \ 0.29\ \ 0.24\ \ 0.07\ \ 0.03]$, *i.e.*, the degree of membership of the first-level indexes.

4.3.3 Third-Level Fuzzy Comprehensive Evaluation

The weight of the first-level index was extracted from Table 5, namely Words $W_u=[0.25\ \ 0.60\ \ 0.15]$,to construct the degree of membership matrix row for the first-level index:

$$R_u=\begin{bmatrix}S_{u_1}\\S_{u_2}\\S_{u_3}\end{bmatrix}=\begin{bmatrix}0.22 & 0.26 & 0.27 & 0.18 & 0.07\\0.25 & 0.28 & 0.30 & 0.13 & 0.04\\0.37 & 0.29 & 0.24 & 0.07 & 0.03\end{bmatrix}$$

Through the multiplication of the matrix, the evaluation result of the first-level index was solved $S_u=W_u\otimes R_u=[0.26\ \ 0.27\ \ 0.28\ \ 0.13\ \ 0.06]$, which served as the final evaluation result. According to the principle of the degree of membership maximization, 0.28 corresponded to the "medium" level in the evaluation set, which completely coincided with the practical situation. This course had the honor to win the title of the school-level excellent online open course in the review organized by the school in 2021, but it still had a way to go to catch up with provincial-level ones, so developers should make efforts to figure out the reasons for such a big gap.

From the above first-level fuzzy comprehensive evaluation results, teaching design, teaching activity, emotional attitude, and intrinsic value were at the "medium" level. Hence, developers should find the causes from aspects of teaching method, teaching content, item analysis, intercommunication, and student-student collaboration, especially, the degree of membership of student-student collaboration to the level was 0.32 (qualified). Given the above results, the following suggestions were provided to course developers:

1) Abandon the traditional teaching method, and adopt the project-imported and task-driven teaching method;

2) Organize teaching activities according to production tasks, and fuse navigation culture and ideological political elements into professional knowledge;

3) Analyze knowledge points and dock with the production process;

4) Use Web2.0 technology to construct learning circles in addition to strengthening the management of interaction modules;

5) Strengthen student-student collaboration and complete operation training of large equipment.

5 CONCLUSIONS

The development of MOOC depends on quality, which is influenced by various factors, thus verifying the complexity and particularity of MOOC quality evaluation. The development of MOOC can be promoted, and its development bottlenecks can be solved by establishing a set of quality evaluation systems for MOOC catering to the subject features and reasonably evaluating MOOC quality. Given this, the following research conclusions were drawn:

1) A set of quality evaluation index systems for MOOC were established with the navigation specialty in higher vocational schools as an example;

2) The index weights at all levels were calculated through the triangular fuzzy AHP, which, compared with the traditional AHP, fully considered the indeterminacy and fuzziness of expert value assignment and contributed to more operable judgment matrices, accompanied by more scientific and reasonable weights determined;

3) Expert scores were fuzzified using normally distributed membership functions so that the determined degree of membership coincided with the reality to a greater extent and the evaluation results were more scientific and reliable.

However, this model is subjected to limitations during research and application. For instance, the calculation method for the degree of membership based on expert scoring proposes high requirements for expert experience, which can be hardly guaranteed in practice. Moreover, mass matrix calculations are needed during the application process of this model. All the above problems are subjects to be investigated and explored in the future.

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