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Research on the Performance Assessment of CMF Design Curriculum Based on Fuzzy Comprehensive Evaluation: Taking the CMF Design of Passenger Interface of High-Speed Train Dining Car as an Example

Jun DU, Ning DAI, Fangyu LI, Tianjiao ZHANG, and Xiaoyan WANG School of Design, Southwest Jiaotong University

Abstract. The purpose of this study is to integrate the fuzzy comprehensive evaluation method into the design scheme evaluation of art and design students and explore the method to improve the course work assessment. On the basis of determining the objectives of curriculum cultivation, the research group proposed a fuzzy comprehensive evaluation method of a curriculum design scheme. Taking CMF design of the passenger interface of a high-speed train as an example, the study attempts to improve the previous issues of difficulty in determining the weights of course design evaluation methods and inaccurate evaluation results. The evaluation index system is established according to the characteristics of CMF curriculum design and the need for teaching reform. The application of fuzzy comprehensive evaluation to CMF design coursework assessment is an innovative attempt for the course teaching reform of art design majors, which has important popularization and application value.

Keywords. fuzzy judgment, CMF design, Passenger interface design, Teaching reform, Course assessment

1. Introduction

In view of the construction of the university-level first-class course "CMF Application and Design", the research group of product design major of Southwest Jiaotong University explores the course design and assessment. CMF literally stands for color, materials and surface treatment processes. CMF design is a key factor in creating emotional products [1]. CMF course, as an important part of the compulsory courses for product design major, mainly teaches the basic knowledge of CMF systematically, guides and cultivates students' design thinking, and the final CMF design scheme becomes the key content of the assessment of students' learning and practical ability. In view of this, the research group tried to apply the fuzzy comprehensive evaluation method to students' CMF design work assessment of the passenger interface of high-speed train dining car and explored the evaluation method of art design course work.

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2. Design scheme and fuzzy comprehensive evaluation method

The reasonable selection of assessment methods and evaluation methods for art and design course assignments in universities is two key factors that determine the success or failure of teaching work.

2.1. Selection of assessment scheme

At the beginning of the course, the teacher constructs a theoretical model of CMF design to guide students to conduct in-depth analysis of the concept and function of CMF design, as shown in Figure 1[3]. Combined with the relevant elements involved in CMF and the basic characteristics of its knowledge structure, it can be summarized into four levels: physical culture, cultural symbols, functional experience, and emotional resonance, so that students can initially form the design direction of "from material form to interactive form".

Secondly, the research group selected the passenger interface CMF design of the dining car of the high-speed train CR400BF, which runs from 3 to 8 hours, as the research object. Passenger interface refers to the internal environment formed by a variety of in-car facilities such as interior wall panels, interior roof panels, doors and Windows, seats, and hardware in the train cabin [4]. The existing standardized train space environment is subject to many restrictive factors. At present, A group of trains only has a sales bar in the second-class passenger car, as shown in area A in Figure 2, and some of its seating area and luggage rack area are respectively shown in areas B and C in Figure 2. The corresponding status quo is shown in Figure 3-A, Figure 3-B and Figure 3-C. Failure to provide passengers with a complete and comfortable dining space alone can lead to awkward, cramped and other psychological states during the use of space [5].

2.2. Scheme assessment method

The fuzzy comprehensive evaluation method is used to evaluate things because things often have multiple attributes, so it is necessary to take into account all aspects when evaluating things, which means multiple evaluation indicators need to be selected, and the properties of these indicators are often fuzzy, therefore, this comprehensive evaluation is called fuzzy comprehensive evaluation [6]. Therefore, the research team consulted three teachers with years of experience in mathematics teaching to give suggestions, and selected four aspects of "innovation, practicality, aesthetics and standardization" as the evaluation indicators. Then, two product design experts from the business community were invited to discuss with the head of the teaching department of the college, and finally agreed to adopt fuzzy comprehensive evaluation in the process of job review.



Figure 1.CMF design theoretical model



Figure 2. Layout of dining car



C area

B area

A area

Figure 3. Current situation of areas A, E and F

3. Fuzzy comprehensive evaluation

Fuzzy comprehensive evaluation is a method of educational evaluation using fuzzy mathematics [7]. Fuzzy mathematics was born in the 1960s, it can be used to consider the influence of various factors related to the things being evaluated, and make a general evaluation of things with the help of the fuzzy transformation principle and maximum membership principle.

3.1. Evaluation mechanism

Since the cognitive process of human beings is from simple to abstract thinking, its cognitive goals are divided into six main categories: knowing, understanding, applying, analyzing, synthesizing and evaluating [8]. The set of proposed comments (the set representing levels, classifications, etc.) as $R = \{r_1, r_2, ..., r_m\}$, with a total of *m* levels; The set of factors is $V = \{v_1, v_2, ..., v_n\}$, a total of *n* factors. Take the single factor

evaluation of the NTH factor as R_n , which can be used as a fuzzy subset on V, where r_{nm} represents the membership degree of the *nth* factor evaluation for the *m* level. The total evaluation matrix R of n factors is:

$$R = \begin{pmatrix} R_1 \\ R_2 \\ M \\ R_n \end{pmatrix} = \begin{pmatrix} r_{11} & r_{12} & \Lambda & r_{1m} \\ r_{21} & \Lambda & \Lambda & r_{2m} \\ \Lambda & \Lambda & \Lambda & \Lambda \\ r_{n1} & \Lambda & \Lambda & r_{nm} \end{pmatrix}$$

When the comprehensive evaluation must consider the effect of each factor on the evaluation level, the evaluation effect forms *A* fuzzy subset *A* on the set of factors,

$$A = (a_1, a_2, ..., a_n)$$

 a_i is the membership degree of v_i to A, which is a measure of the effect of factors on the evaluation grade, indicating the ability to evaluate the grade according to a single factor v_i ; The value is given based on experience.

After determining A and R, a comprehensive evaluation can be carried out. The operation form is $B=A\sigma R$, σ is a fuzzy composite operator. The overall process is represented by the block diagram as follows:



According to the CMF design characteristics of the passenger interface of the train restaurant [9], the research group adopts a special "weighted average type" fuzzy comprehensive evaluation, whose fuzzy composite operator is $\sigma = (\bullet \oplus)$, where \oplus represents the ring sum, defined as $|\alpha \oplus \beta| = \min\{1, \alpha + \beta\}$ and the ring sum does not

exceed 1. $\bigoplus_{i=1}^{n}$ represents the sum of *n* numbers under the \oplus operation,

$$b_j = \bigoplus_{i=1}^n a_i \cdot r_{\mathcal{Y}} = min\left\{1, \sum_{i=1}^n a_i r_v\right\}$$

Where $bj \in B$.

Make a fuzzy comprehensive judgment def fuzz_synthesis(evaluation_matrix, weights): # Calculate the membership of each element single_values = np.zeros(len(evaluation_matrix)) for i in range(len(evaluation_matrix)): for j in range(len(evaluation_matrix[i])): single_values[i] += weights[j] * evaluation_matrix[i][j] # Normalizes membership values single_values /= np.sum(single_values) # Calculate the comprehensive evaluation results synthesis_value = np.sum(weights * single_values) return synthesis_value

3.2. Case Evaluation

Figure 4 and Figure 5 show the students' work design scheme of "CMF design of high-speed train restaurant passenger interface". First of all, students adjusted the existing layout in Figure 2, and changed the original three sections A, B and C in Figure 2 into four sections E, F, T and O in Figure 4 to meet the needs of passengers for the dining car. In order to facilitate the study, this paper selects the virtual reality renderings of F and E regions for evaluation, as shown in Figure 5.



Figure 4. Dining car layout of the modified CR400BF high-speed train



E area

F area

Figure 5. Renderings of areas E and F

Assignment requirements for high-speed train passenger interface design: Students need to design a comfortable, beautiful and ergonomic interior space from the perspective of color, material, surface treatment, etc[10].

	CMF innovation	Practicality	Aesthetics <i>u</i> ₁₃	Standardization
	u ₁₁	u ₁₂		u ₁₄
Review Teacher 1	92	95	93	100
Review Teacher 2	95	94	97	90
Review Teacher 3	98	95	93	95

Table 1. Figure 5-F transcript

For the redesigned dining area environment shown in Figure 5-F, the course team selected three reviewing teachers to give numerical evaluation, as shown in Table 1; The teacher made three rating levels: "excellent, good, medium"; The weight distribution is given: innovative 40%, practical 35%, aesthetic 20%, normative 5%.

(1) Determine the set of first-level factors as $u1 = \{innovation, practicality, aesthetics, standardization\}$

(2) Determine the weight distribution of first-level factors, that is, the fuzzy subset of evaluation weights is

 $A_{I} = (0.40\ 0.35\ 0.20\ 0.05)$

(3) Determine the evaluation language set as

 $v_I = \{\text{Excellent, Good, Acceptable}\}$

For the normalization of the single score in Table 1, it is divided by a full score of 100 (as the maximum membership degree 1), there is

$$u_{11} = \{\text{innovation}\} = (0.92 \ 0.95 \ 0.98)$$

 $u_{12} = \{\text{practicality}\} = (0.95 \ 0.94 \ 0.95)$

$$u_{13} = \{ aesthetics \} = (0.93 \ 0.97 \ 0.93)$$

$$u_{14} = \{\text{standardization}\} = (1.00\ 0.90\ 0.95)$$

According to the above data, the fuzzy relation matrix is formed,

$$R_1 = \begin{pmatrix} 0.92 & 0.95 & 0.98 \\ 0.95 & 0.94 & 0.95 \\ 0.93 & 0.97 & 0.93 \\ 1.00 & 0.90 & 0.95 \end{pmatrix}$$

Calculate $B_1 = A_1 \sigma R_1$,

$$B_{1} = (0.40 \ 0.35 \ 0.20 \ 0.05)\sigma \begin{pmatrix} 0.92 & 0.95 & 0.98 \\ 0.95 & 0.94 & 0.95 \\ 0.93 & 0.97 & 0.93 \\ 1.00 & 0.90 & 0.95 \end{pmatrix} = (0.94 \ 0.95 \ 0.96)$$

After normalization processing, we get:

$$B_1 = (0.330 \quad 0.333 \quad 0.337)$$

According to the "maximum membership principle", the corresponding evaluation grade is very good.

Table 2. Figure 5-E transcript

	CMF innovation	Practicality u12	Aesthetics <i>u</i> ₁₃	Standardization u14
	u ₁₁			
Review Teacher	good	good	acceptable	excellent
1				
Review Teacher	good	good	good	acceptable
2				
Review Teacher	excellent	good	acceptable	good
3				

For the redesigned high speed train dining car bar as shown in Figure 5-E, the reviewing teachers took language as the evaluation method, as shown in Table 2; The teacher set three assessment levels:

"Excellent, very good, good"; The weight distribution is given: innovative 40%, practical 35%, aesthetic 20%, normative 5%.

As shown above,

(1)Determine the set of first-level factors as u_2 ={innovative, practical, aesthetic, normative}

(2) Determine the weight distribution of first-level factors, that is, the evaluation weight

The fuzzy subset is $A_2 = (0.40\ 0.35\ 0.20\ 0.05)$

(3)Establish that the evaluation language set is V_2 ={excellent,very good, good} For the normalization of individual results in Table 2, there is

$$u_{21} = \{innovative\} = \begin{pmatrix} \frac{1}{3} & \frac{1}{3} & \frac{2}{3} \\ \frac{1}{3} & \frac{2}{3} \end{pmatrix} \quad u_{22} = \{practical\} = \begin{pmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{1}{3} & \frac{1}{3} \end{pmatrix}$$
$$u_{23} = \{aesthetic\} = \begin{pmatrix} \frac{0}{3} & \frac{2}{3} & \frac{0}{3} \\ \frac{1}{3} & \frac{1}{3} \end{pmatrix} \quad u_{24} = \{normative\} = \begin{pmatrix} \frac{2}{3} & \frac{0}{3} & \frac{1}{3} \\ \frac{1}{3} & \frac{1}{3} \end{pmatrix}$$

According to the above data, the fuzzy relation matrix is formed,

$$R_2 = \frac{1}{3} \begin{pmatrix} 1 & 1 & 2 \\ 1 & 1 & 1 \\ 0 & 2 & 0 \\ 2 & 0 & 1 \end{pmatrix}$$

Calculate $B_2 = A_2 \sigma R_2$,

$$B_2 = (0.40 \quad 0.35 \quad 0.20 \quad 0.05)\sigma \frac{1}{3} \begin{pmatrix} 1 & 1 & 2 \\ 1 & 1 & 1 \\ 0 & 2 & 0 \\ 2 & 0 & 1 \end{pmatrix} = \frac{1}{3} (0.85 \quad 1.15 \quad 1.20)$$

After normalization processing, we get:

$$B_2 = (0.266\ 0.359\ 0.375)$$

According to the "maximum membership principle", the corresponding evaluation grade is good.

Table 3. Evaluation of Figure 5-F by ordinary weighting method

	CMF innovation	Practicality	Aesthetics	Standardization	
Individual average score	95	95	94	95	
evaluation weight	0.40	0.35	0.20	0.05	
total score	0.40*95+0.35*93+0.20*94+0.05*95=94.1				

3.3. Evaluation and Discussion

In the evaluation of CMF design work, if the "ordinary weighting method" is adopted, then the results of Figure 4-F are shown in Table 3: it is very obvious that the final score corresponds to the evaluation level of excellent (stipulated: excellent is not less than 90 points, good is 80 to 89 points, and good is less than 80 points). It is two levels higher than the conclusion of "fuzzy comprehensive evaluation". Therefore, in theory, a fuzzy comprehensive evaluation is "better" than the ordinary weighted method, and the conclusion is more reliable and scientific. Although the "general weighted scoring method" assigns different weights to evaluation indicators, its calculation is still a simple total score addition method in essence, so it is difficult to truly reflect the difference in weights. "Fuzzy comprehensive evaluation method" is the extension of the "general weighted method", which has the characteristics of more accurate and more subdivided. It can not only reflect the value of weight, but also reflect the comprehensive impact of various factors. For the language evaluation method used in Figure 4-E, the final evaluation can only be completed through the conversion process of "language evaluation \rightarrow score value \rightarrow language evaluation". In this process, the uncertainty of the information content of the evaluation index is inevitably increased,

and it is difficult for students to understand and improve.

4. Conclusion

The evaluation of the CMF design course contains a lot of emotional factors [11], which makes the evaluation difficult to quantify. Taking the interface design of passenger dining cars for high-speed trains as an example, the research group found that it was difficult to explain the substantial difference between the 83-point design scheme and the 88-point design scheme by using score evaluation; The use of language evaluation methods can make the evaluator overlook many valuable information in the homework, and the evaluation results are often not objective and accurate enough, leading to a dilemma in homework assessment. However, the introduction of fuzzy mathematics into the coursework assessment can optimize the evaluation method. In art design course assignment, the fuzzy comprehensive evaluation method can not only overcome the difficulty of evaluation, but also evaluate the design scheme objectively, or it will become a new choice of art design evaluation mode.

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