WARSAW UNIVERSITY OF TECHNOLOGY Index 351733
FACULTY OF CIVIL ENGINEERING
COMMITTEE FOR CIVIL AND WATER ENGINEERING
POLISH ACADEMY OF SCIENCES ISSN 1230-2945
DOI: 10.24425/ace.2026.1403
ARCHIVES OF CIVIL ENGINEERING
Vol. LXXII ISSUE 3 2026
pp. 431 –444

Research paper

Teaching practice of cultural heritage and innovation of architectural interior art design based on fuzzy decision-making

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Abstract: The abstract must be written as one paragraph. It needs to be informative and short. Do not use symbols, special characters, or math in the paper title or abstract. The abstract should not contain displayed mathematical equations or tabular material. The current research on architecture pedagogy is in the stage of deep transformation and active exploration. This paper proposes and practices a new teaching mode based on fuzzy decision-making theory to meet the challenges of cultural heritage and innovation in the field of architectural interior art design in the context of globalization. A teaching system integrating cultural heritage and innovation is constructed, aiming at cultivating students to use fuzzy decision-making theory to identify, evaluate and select cultural elements in the design process, and at the same time, improving comprehensive judgment and innovation ability. The experimental study shows that the students in the experimental group taught with fuzzy decision-making theory have significantly improved their cultural cognitive understanding, design decision-making ability and innovative thinking, and successfully applied fuzzy decision-making theory to quantitatively evaluate the cultural elements in their practical projects, realizing the high quality of their design works in terms of cultural connotation, innovativeness, and practicality and aesthetics.

Keywords: fuzzy decision making, architecture, interior art design, cultural heritage and innovation, education

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1. Introduction

As a bridge between architectural theory and practice, tradition and innovation, architectural education plays an irreplaceable and key role in cultivating professional talents, promoting industry development, and inheriting and innovating architectural culture [1]. From the perspective of professional talent training, it provides students with a systematic and comprehensive knowledge system covering architectural history, theory, design methods, engineering technology and other aspects, so that students can not only master solid professional skills, but also have keen design perception and innovative thinking, and provide fresh blood for the construction industry [2].

Architectural education is an important position for the inheritance and innovation of architectural culture. It shoulders the mission of inheriting historical and cultural heritage, allowing students to have a deep understanding of the architectural styles and cultural connotations of different regions and periods, and absorb traditional architectural wisdom [3]. On this basis, we will stimulate students' innovative spirit and encourage them to incorporate traditional elements into modern design, so as to achieve the creative transformation and innovative development of architectural culture and make the ancient architectural culture shine with new vitality in contemporary society [4, 5].

The specific close relationship between interior art design and cultural heritage is specifically shown in Fig. 1.

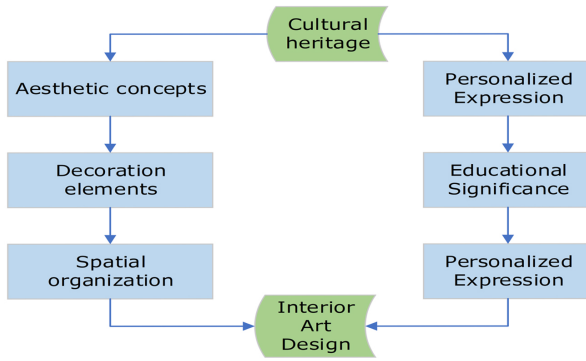

Fig. 1. Relationship between interior art design and cultural heritage

This study aims to explore and practice the new teaching mode of cultural heritage and innovation of architectural interior art design based on fuzzy decision-making [6]. The goal of the study is to build a teaching system that can respect and effectively transmit the essence of traditional culture, while encouraging and stimulating students' potential for innovation, so as to promote the development of China's architectural interior art and design education, and to cultivate design talents with both profound cultural heritage and forward-looking innovation ability [7]. We will focus on how to integrate the fuzzy decision-making theory into teaching activities, and guide students to learn to use scientific decision-making methods when facing the choice of cultural heritage and innovation, to fully explore and show the unique charm of

the excellent traditional Chinese culture, and at the same time, actively respond to the changes of the times, and be brave to make breakthroughs, so as to realize the double sublimation of the architectural interior art design in terms of cultural connotation and formal expression [8].

2. Literature review

2.1. Cultural inheritance and innovation of interior art design

The cultural inheritance and innovation of interior art design have both theoretical and practical significance. They are related to how the design discipline can inherit historical culture on the basis of innovation and give modern space unique charm and contemporary atmosphere. In recent years, relevant academic research has become more and more in-depth.

Many scholars focus on the historical accumulation and core value of regional characteristics of design culture. They believe that each interior space carries the historical memory and cultural genes of a specific period and region, which can be revitalized in new designs after being refined and reconstructed [9]. It is advocated that through systematic research and cultural interpretation, cultural resources such as historical architectural art, folk crafts, and local materials should be creatively integrated into modern interior design to achieve the living inheritance and sustainable use of cultural resources. At the same time, the future path of interior art design is explored from an innovative perspective, so that the design works can not only demonstrate the profound cultural heritage, but also meet the aesthetic and functional needs of modern society, and achieve the interactive symbiosis of cultural inheritance and innovation [10]. Intelligent innovation is reflected in the understanding and application of new materials, technologies and new lifestyles. Interdisciplinary cooperation helps interior art design break through boundaries and create design solutions that are both culturally meaningful and forward-looking. In general, the research on cultural inheritance and innovation in the field of interior art design is becoming more mature [11].

2.2. Current problems in the teaching of architectural interior art design

Although the teaching of architectural interior art design has achieved remarkable results in the past few decades, facing the rapidly changing times and increasingly complex industry needs, there are still many problems and challenges that cannot be ignored, especially in cultural inheritance and innovative education [12].

Some studies have pointed out in-depth analysis of the current teaching situation that the current teaching model relies too much on theoretical knowledge teaching and lacks in cultivating students' practical hands-on and traditional cultural elements [13]. This imbalance makes it difficult for students to transform rich cultural connotations into intuitive design expressions when they create, limiting the development of their design and innovation capabilities [14]. Regarding the teaching integration of fuzzy decision theory, some people point out that although the academic community's understanding of this theory continues to deepen, in teaching practice, it is still a difficult problem to effectively embed it into the

curriculum system, closely combine it with design projects and case studies, and guide students to flexibly use this theory to make multi-dimensional design decisions. Specifically, how to let students experience the practicality and universality of fuzzy decision theory in dealing with design problems in actual operations through courses and experimental teaching is the key to be solved urgently [15].

3. Fundamentals of fuzzy decision theory in teaching architectural interior art and design

Fuzzy Decision Theory, as an effective tool for dealing with uncertainty and ambiguity, provides designers with new perspectives and solutions when facing the demands of complex and changing interior environments. And applying it to the teaching of architectural interior art design can help students better understand and cope with the complex and changing design challenges in the real world. These four parts are interrelated and together constitute the application framework of fuzzy decision theory in the teaching of architectural interior art design.

3.1. Analysis of the basic principles of fuzzy decision theory and its applicability in design decisions

In the teaching and practice of architectural interior art design, fuzzy decision-making theory shows wide applicability and powerful flexibility. In the early stage of design, designers often encounter many uncertainties that cannot be precisely quantified, such as users' personal preferences, the diversity of functional needs of the space, and the ambiguity of judgment standards due to differences in aesthetic concepts, etc. The fuzzy decision- making theory becomes an effective tool [16]. At this point, the fuzzy decision theory becomes an effective tool, which can transform the original abstract and subjective evaluation criteria into quantifiable affiliation function values by constructing and applying fuzzy linguistic evaluation sets, and then carry out comprehensive judgment based on fuzzy logic operations [17].

In the specific operational process, we first need to predetermine the weights of each evaluation indicator. The determination of weights should be based on the understanding and analysis of the importance of each indicator, while also taking into account the actual situation and specific needs. For example, in some design solutions, appearance and functionality may be more important, and therefore should be given a higher proportion in the weight allocation. In other solutions, cost and environmental friendliness may be more important, so the weight allocation should be adjusted accordingly. $V = \frac{\sum_{i=1}^{5} w_i \times U_i}{\sum_{i=1}^{5} w_i}$. Where V is the overall fuzzy evaluation vector of the design scheme, is the fuzzy evaluation vector of each evaluation index, and is the weight of the corresponding evaluation index [18, 19].

3.2. Discussion on identification and quantification of fuzzy factors in architectural interior art design

3.2.1. Identification of fuzzy factors and their sources of ambiguity

In the field of architectural interior art design, there are many fuzzy factors, and the uncertainty of these factors mainly stems from the following points. The first is the subjectivity for the user's needs and experience: the user's satisfaction of the space (UserSatisfaction, US) contains multiple dimensions such as aesthetic perception, comfort and functional needs, and these factors often have obvious subjectivity and individual differences, forming a fuzzy set $US = US_{\text{excellent}}, US_{\text{good}}, US_{\text{average}}, US_{\text{poor}}, US_{\text{verypoor}}$. Secondly, the diversity and adaptability of spatial functions, Functional Adaptability (FA) refers to the degree of fulfillment of the design solutions to the diversity and future variability needs, which is expressed as a fuzzy set $FA = FA_{\text{highly adaptable}}, FA_{\text{adaptable}}, FA_{\text{moderate}}, FA_{\text{less adaptable}}, FA_{\text{very adaptable}}$. Complexity of Environmental Response: Environmental Response (ER) includes the response to changes in environmental conditions such as Lighting (L), Acoustics (A), Temperature (T), etc., which forms a fuzzy set $ER = ER_{\text{optimal response}}, ER_{\text{good response}}, ER_{\text{moderate response}}, ER_{\text{poor response}}, ER_{\text{very poor response}}$. These factors are fuzzy because they depend on subjective evaluations, uncertainty of future demand, and dynamic changes in environmental parameters.

3.2.2. Fuzzy set construction and fuzzy quantization methods

The quantification of fuzzy factors is a complex and delicate process. Fuzzy factors, usually refer to variables or factors that cannot be easily and clearly defined and are characterized by uncertainty. The quantification of fuzzy factors is crucial in a number of fields such as decision analysis, risk management, and predictive modeling, as it helps to transform uncertainty into operational mathematical representations for more accurate analysis and prediction. We use the following approaches in our research.

Expert scoring method: Experts quantitatively evaluate the performance of the design solutions on each fuzzy factor based on their professional knowledge and experience. The degree of affiliation of design option D in the "excellent" level of user satisfaction is calculated as: $\mu_D(US_{\text{excellent}}) = \text{Expert Rating}(D, US_{\text{excellent}})$.

Questionnaire method: By counting the results of the user survey, the affiliation degree of Design Option D in the "good" satisfaction level is calculated:

$$\mu_D(US_{\text{good}}) = \frac{\text{Number of Votes for Dat } US_{\text{good}}}{\text{Total Votes for D}}.$$

Fuzzy inference method: combining design parameters and expert knowledge, using fuzzy logic to evaluate multiple sub-factors comprehensively, e.g., calculating comfort C: $\mu_D(C, C_{\text{grade}}) = \text{Fuzzify}(\text{Aggregation}(\mu_D(T, T_{\text{grade}}), \mu_D(L, L_{\text{grade}}), \mu_D(A, A_{\text{grade}}))$. Where Fuzzify denotes the fuzzification process and Aggregation can be a weighted average, fuzzy operator or other composite operations. In addition, for fuzzy quantization, Analytic Hierarchy Process, AHP or Fuzzy Analytic Hierarchy Process, FAHP can be used to determine the weights of each factor to improve the accuracy and rationality of evaluation. In conclusion, in the teaching of architectural interior art design, fuzzy decision theory provides a powerful tool for identifying, quantifying and dealing with fuzzy factors.

In architectural teaching, fuzzy decision theory realizes the quantification and scientific evaluation of uncertain factors through fuzzy set modeling, weight calculation, fuzzy reasoning system and comprehensive evaluation analysis. First, fuzzy set modeling converts subjective factors such as spatial comfort, aesthetics and functionality into mathematical expressions, making the evaluation criteria computable. Secondly, weight calculation methods such as fuzzy analytic hierarchy process (FAHP), entropy weight method and Delphi method ensure the reasonable distribution of the importance of different indicators and improve the scientific nature of decision-making. Subsequently, the fuzzy reasoning system (FIS) realizes the comprehensive evaluation of the design scheme through steps such as fuzzification, rule reasoning and defuzzification. The whole process includes determining the evaluation target, data collection and fuzzification, weight calculation, fuzzy reasoning and comprehensive analysis, and finally optimizing the design scheme. Commonly used tools such as MATLAB (Fuzzy Logic Toolbox), Python (skfuzzy library) and Excel VBA improve the calculation efficiency and decision accuracy. Through the application of fuzzy decision theory, architectural interior art design teaching can more systematically cultivate students' ability to cope with complex design challenges and make the design scheme more scientific and reasonable.

4. Construction of cultural heritage and innovation teaching mode of architectural interior art design based on fuzzy decision making

4.1. Teaching goal setting

When constructing the teaching mode of architectural interior art design based on fuzzy decision-making theory, the first task is to set a refined teaching goal. This goal aims to strengthen the depth and breadth of students' knowledge of cultural connotations in design, and guide them to explore the possibility of design innovation by using the principle of fuzzy decision-making while respecting and inheriting traditional culture.

We emphasize the teaching objectives of cultural identity and in-depth interpretation, so that students can use the fuzzy set theory of fuzzy decision theory to understand and interpret art and design elements in different cultural contexts, and form a dynamic and inclusive cultural value evaluation system. This not only includes the understanding of the historical origin, symbolic meaning and aesthetic characteristics of traditional elements, but also the need to transform these abstract concepts into quantifiable fuzzy evaluation functions.

4.2. Instructional design

In the design of teaching content, we emphasize the integration of fuzzy decision-making theory into the teaching process of architectural interior art design, in order to help students respect and inherit the traditional culture, while at the same time, its innovative application. The following are the specific implementation program and teaching details:

1. Application of fuzzy decision-making theory in the identification and evaluation of cultural elements: Students are guided to use fuzzy decision- making theory to construct a complete evaluation system of cultural elements, covering multiple indicators such as cultural symbolism, aesthetic value, functional adaptability and innovation potential. For example, for a certain traditional decorative element, through expert consultation and literature research, its performance in different evaluation dimensions is quantified as a fuzzy affiliation function: Cultural Element$_i$ = [μ_i(Symbolic Meaning), μ_i(Aesthetic Value), μ_i(Functionality), μ_i(Innovation Potential)], and further through the construction of fuzzy evaluation matrix, the fuzzy evaluations of each cultural element on different indicators are systematically organized and compared.
2. Practice of fuzzy decision-making method in the selection of cultural elements and innovative design: In specific design projects, students are encouraged to use fuzzy decision-making method to comprehensively judge and prioritize the alternative cultural elements according to the design objectives and market demands. By calculating the fuzzy comprehensive judgment value: Optimal Cultural Element = $\arg\max_{C_i} \sum_{j=1}^{m} w_j \cdot \mu_j(C_i)$.

In this experiment, there are 30 undergraduate students majoring in architectural interior art design in the experimental group. The experimental process is as follows: At the beginning of the semester, a two- week intensive training on fuzzy decision theory was arranged. Through theoretical explanations and case analysis, students were systematically taught the relevant knowledge of fuzzy decision theory. After the training, a series of representative architectural interior design cases were introduced, and students were organized to use the learned theories in groups to deeply analyze the cultural heritage and innovative design, and compare the differences between fuzzy decision-making methods and traditional methods in identifying and evaluating traditional elements.

4.3. Teaching strategies

In the teaching practice of architectural interior art design, fuzzy decision-making theory is taken as the core of the teaching implementation strategy, aiming at cultivating students to effectively integrate traditional cultural elements and modern design concepts to realize cultural inheritance and innovation in complex and uncertain design decision-making situations. Teachers should select a series of ancient and modern architectural interior design cases, focusing on analyzing how designers use fuzzy decision-making theory to deal with the inheritance and innovation of cultural elements. For example, by interpreting how the Suzhou Museum designed by I.M. Pei skillfully integrates the traditional architectural style of the Jiangnan water town with modern minimalist design concepts, students are guided to understand the application of fuzzy decision-making in design decision-making and are encouraged to use the fuzzy evaluation model to analyze the case secondly in the seminar. Teachers design and implement a series of simulation and practical projects to allow students to personally participate in the process of using fuzzy decision-making theory to select cultural elements and innovative design. For example, a design task is assigned that requires students to use fuzzy decision theory to evaluate and select the degree of integration and formal innovation of traditional Chinese elements (e.g., window panes, screens, carvings, etc.) when designing a modern living space.

The school offers special lectures and seminars to explain in detail the basic principles and application methods of fuzzy decision theory, such as fuzzy set theory, fuzzy evaluation matrix construction, and fuzzy comprehensive judgment. Subsequently, the theoretical knowledge is applied to actual design projects through practical courses, such as constructing a fuzzy evaluation system applicable to architectural interior art design, and using software tools (e.g., MATLAB, FuzzyTECH, etc.) for fuzzy decision-making simulation and calculation. On the other hand, students are guided to cross the multidisciplinary boundaries of design, history, culture, psychology, etc., and use fuzzy decision-making theory to deal with fuzzy factors among interdisciplinary disciplines, so as to cultivate cross-boundary thinking and innovative decision-making ability of students. For example, through the fuzzy evaluation of user behavior and psychological needs, students are guided to realize the precise putting of cultural heritage and innovation in design. The implementation idea of the teaching strategy is shown in Fig. 2.

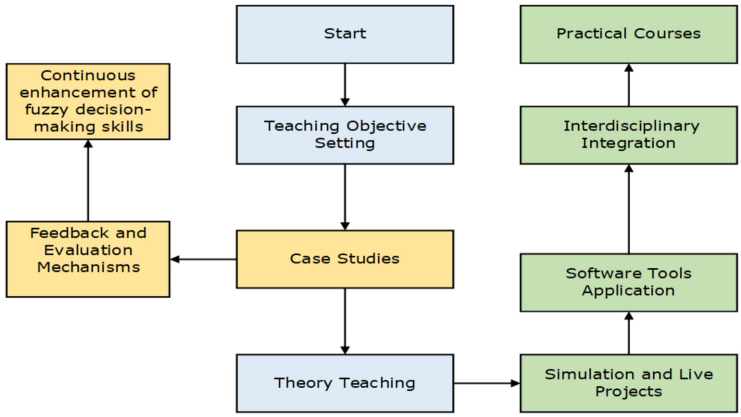

Fig. 2. Ideas for implementing teaching strategies

Through the above teaching implementation strategies, fuzzy decision-making theory can be effectively integrated into the teaching practice of architectural interior art design to cultivate students' comprehensive judgment and innovation ability, so that they can use modern language to express innovation while respecting the traditional culture, thus realizing the perfect integration of cultural heritage and innovation in the design field.

5. Experimental evaluation

5.1. Experimental design and implementation

In order to deeply investigate the practical efficacy of fuzzy decision- making theory in the teaching of cultural inheritance and innovation of architectural interior art and design, this study elaborately designed and implemented a one-semester teaching experiment. The research subjects were N undergraduate students majoring in architectural interior art and design, who were divided into the experimental group and the control group through strict

random assignment. The students in the experimental group received a new teaching model centered on fuzzy decision-making theory, which covered the following three phases: (1) At the beginning of the semester, the students in the experimental group received systematic training on fuzzy decision-making theory, which included but was not limited to fuzzy set theory, fuzzy evaluation methods, and fuzzy decision-making models, and was designed to guide the students to understand and master how to apply the fuzzy decision-making theory in the actual design decision-making process. (2) The researchers selected a series of representative architectural interior art design cases, and encouraged the students in the experimental group to use the learned fuzzy decision theory to analyze the cultural heritage and innovative design in the cases in depth. By comparing the advantages of the fuzzy decision-making method in recognizing and evaluating the traditional elements, it contrasts with the conventional method. (3) Students in the experimental group participate in a design practice project, which requires them to use fuzzy decision theory to quantitatively evaluate cultural elements in their design proposals and try to find the best balance between respecting traditional design and pursuing innovative design. The control group followed the traditional teaching method, which did not involve the teaching of fuzzy decision theory. Prior to the launch of the experiment, all participants were pretested to examine their basic knowledge, design decision-making ability, and level of innovative thinking in the field of cultural heritage and innovative design.

5.2. Measurement indicators and tools

In this study, a series of diversified assessment indicators were chosen, including cultural cognitive understanding, design decision-making ability, level of creative thinking, and quality of work. A series of experiments were conducted to address these indicators.

Table 1 demonstrates the mean scores and their variances of the students in the experimental and control groups on the cultural cognitive understanding test after receiving fuzzy decision theory instruction versus conventional instruction. The experimental results show that the mean scores of the students in the experimental group are higher than those of the control group, indicating that the teaching of fuzzy decision theory has the potential to enhance students' cognitive understanding of the cultural elements in the design of architectural interior art and the sense of inheritance.

Table 1. Table of students' scores on the cultural cognitive understanding test

Groups	Average score	Variance (statistics)	p value
experimental group	78.25	0.95	0.003
control subjects	72.34	0.88	–

Table 2 reflects the performance of the experimental group and the control group in design decision-making ability. The experimental data show that the experimental group that received instruction in fuzzy decision theory had better mean scores and variance than the control group in the test of design decision-making ability, implying that fuzzy decision theory plays a positive role in enhancing students' decision analysis and strategy formulation ability.

Table 2. Design decision making capacity assessment form

Groups	Average score	Variance (statistics)	p value
experimental group	81.47	0.67	0.0021
control subjects	75.32	0.78	–

Table 3 assesses the differences between the experimental group and the control group in terms of the level of innovative thinking by means of questionnaires. The mean score and variance of the students in the experimental group were greater than those in the control group, showing that the teaching of fuzzy decision theory helps to stimulate the students' innovative thinking and encourages them to combine traditional and modern elements in their designs, realizing the integration of cultural heritage and innovation.

Table 3. Results of the questionnaire on the level of innovative thinking

Groups	Average score	Variance (statistics)	p value
experimental group	85.13	0.92	0.0019
control subjects	80.56	0.89	—

In Table 4, the results of the experimental and control groups' fuzzy evaluations of the 10 different cultural design elements are compared for their fuzzy evaluations in the practice program. The mean and variance of the experimental group's evaluation on most of the cultural elements are better than that of the control group.

Table 4. Fuzzy evaluation matrix for practice programs

Design elements	Experimental group evaluation mean	Experimental group evaluation variance	Control Group Evaluation Mean	Control group evaluation variance
Cultural Element A	0.82	0.03	0.65	0.02
Cultural Element B	0.79	0.04	0.60	0.03
Cultural Element C	0.85	0.05	0.63	0.04
Cultural element D	0.80	0.02	0.68	0.03

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Table 4 – *Continued from previous page*

Design elements	Experimental group evaluation mean	Experimental group evaluation variance	Control Group Evaluation Mean	Control group evaluation variance
Cultural Element E	0.83	0.04	0.66	0.02
Cultural Element F	0.77	0.03	0.64	0.03
Cultural Element G	0.81	0.04	0.67	0.02
Cultural Element H	0.84	0.03	0.69	0.04
Cultural Element I	0.78	0.05	0.70	0.03
Cultural Element J	0.76	0.04	0.62	0.02

Table 5 provides a comprehensive evaluation of the works of the experimental and control groups in terms of four dimensions: cultural heritage, innovativeness, aesthetics and practicality. The mean score and variance of the experimental group in these four dimensions are higher than that of the control group, confirming that the teaching of fuzzy decision theory helps to improve the overall quality and competitiveness of students' design works.

Table 5. Comprehensive evaluation of the quality of the work

Evaluation indicators	Mean score of the experimental group	Experimental group variance	Mean score of control group	Control group variance	p value
cultural heritability	4.52	0.09	4.01	0.08	0.003
innovativeness	4.68	0.07	4.23	0.09	0.0011
aesthetics	4.59	0.08	4.12	0.07	0.002
practicality	4.45	0.06	3.98	0.08	0.001

Fig. 3 and Table 6 summarize the performance differences between the experimental group and the control group under each assessment index, which visually demonstrates that in the four aspects of cultural cognitive understanding, design decision-making ability, innovative thinking level and comprehensive evaluation of the quality of the works, the experimental group has a significant advantage compared with the control group. Through comparison, it can be seen that the teaching of fuzzy decision theory has a significant effect on improving the ability of students majoring in architectural interior art design in cultural heritage and innovation.

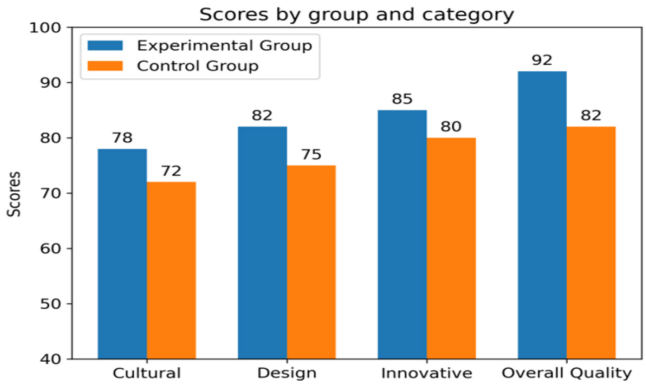

Fig. 3. Comparison table of the performance of the experimental group and the control group

Table 6. Comparison of experimental and control group scores

Measurement indicators	Experimental group variance	Control group variance
Cultural Cognitive Understanding	0.95	0.88
Design decision-making capability	0.67	0.78
Level of innovative thinking	0.92	0.89
Comprehensive evaluation of the quality of the work	0.08	0.08

5.3. Experimental summary and insights

The study shows that fuzzy decision-making theory plays a significant role in promoting the education of architectural interior art design. Students in the experimental group made significant progress in cultural cognitive understanding after receiving relevant teaching, which was manifested in a deeper cognitive understanding and comprehension of traditional elements, reflecting the positive role of fuzzy decision-making theory in cultural heritage education. The students in the experimental group also enhanced their design decision-making ability, and they were able to use the fuzzy decision-making theory to make decisions more effectively in the face of design problems, which showed the practical effect of the theory in enhancing the students' logical thinking and judgment in design decision- making. At the same time, the level of innovative thinking also increased significantly, both in self-assessment and peer assessment, the experimental group's innovative thinking performance exceeded that of the control group, which confirmed the positive effect of the fuzzy decision theory on broadening design horizons and activating innovative consciousness.

At the practical level, the students in the experimental group successfully applied the fuzzy decision theory to the design practice projects, which not only can quantitatively assess the cultural elements, but also can realize a good balance between traditional and innovative

design, and their design works gained a higher evaluation in terms of cultural inheritance, innovativeness, aesthetic value, and practicability, which fully demonstrates the value of the application of fuzzy decision theory in practice. Comprehensively, students in the experimental group outperformed the control group in all assessment indexes, which strongly proves that the teaching of fuzzy decision theory has a positive role in promoting the comprehensive ability of students majoring in architectural interior art and design.

6. Conclusions

This study explores the application of fuzzy decision-making theory in architectural interior art and design teaching. Through teaching reform and experimental evaluation, it shows the theory's positive impact on students' design and innovative thinking. Experimental results indicate that students in the experimental group, after fuzzy decision-making theory teaching, have deeper cultural understanding, better design decision-making logic, and more innovative thinking. They can creatively blend traditional and modern elements in design, producing high-quality works. However, there are areas for improvement. Dynamically adjusting the fuzzy decision model and teaching strategy according to students' learning and project needs for more personalized teaching is a future challenge. Also, quickly incorporating industry trends and new concepts into teaching content, combined with fuzzy decision-making theories, is crucial to keep education current.

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Received: 2024-10-10, Revised: 2025-01-15