Application of Fuzzy-Taguchi theory in the optimization of teaching method and process design

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Abstract. Based on the design of the case reference teaching method, this study designs the teaching materials case through the design concept, class summary, evaluation, and teaching analysis. Innovative teaching method and course design optimization combined analysis mode with Fuzzy-Taguchi theory. The first use of the fuzzy theory system is combined with Taguchi L9 (orthogonal-table) to obtain high-precision experimental results with the smallest number of experimental designs, thereby developing the best design combination. The first paragraph describes the research motivation and instructional design concepts. The second paragraph analyzes various forms of teaching methods and their characteristics through a literature review. Third paragraph using Fuzzy-Taguchi theory to research and develop the teaching method and the analysis mode of the optimal combination of course design. Fourth paragraph summarizes the teaching practice results, including the research, practice, analysis, innovation and contribution of the promotion and reproduction of the teaching design.

Keywords: teaching design, Taguchi, fuzzy, optimization.

1. Introduction

In response to technological development, universities in various countries have increased the proportion of operational application courses to provide and reserve talents for the future industry. With the most popular mobile APP interactive design, it has received the most attention and research. In response to this trend, the optometry department of our university has arranged a course of mobile APP combined with optometry professional (visual-interactive-design). Starting from this scope, this paper carries out innovative teaching methods and process design, develops optimal combination models, comprehensively improves teaching quality, and helps teachers realize teaching effectiveness in the classroom.

This practical course adopts group learning, and after explaining the operation essentials in the lectures, the same and different textbook case exercises are applied to the operation methods, and they are actually applied in the teaching practice research, and the optimized combination analysis mode developed by the practical results is applied. To obtain an optimized combination of curriculum design
and curriculum design to enhance the learning motivation of students who grow up in the technological environment, and to cultivate students' future competitiveness.

2. Literature discussion
The most troublesome problem for teachers is how to effectively enhance students’ interest in learning. Research documents show that there are various teaching methods for practical courses in Taiwan. The teaching methods commonly used in classroom teaching include case-reference method, lecture-demonstration method and driven-task method.

"Case-reference method" is a teaching method based on cases, teachers-led, and students as the main body. It is also a kind of teaching method that researchers pay more attention to. At present, relevant research directions include organizational case teaching, research from the principles that case teaching design should follow, or research on case teaching. For example, Zhao Li(2008) proposed from the introduction, interspersed, discussion, and organizational thematic debate[1]. Yu Lianjun(2010) pointed out that case selection should be hierarchical, students should be interested, increase students' participation, and improve the opportunities for teaching practice and evaluation should be based on encouragement[2]. Zhang Zhiwei(2016) proposed four steps, case selection, implementation, feedback, introspection[3].

According to literature discussion and analysis, most of the research scope is the discussion of teaching method types or the effectiveness of teaching evaluation... etc. However, there are relatively few studies on teaching methods and process design and applied to the classroom. In other words, most teaching methods focus on theoretical discussions, but there is less research in the field of practical application in the classroom and the optimal combination analysis after practice. Therefore, this research aims to make students truly become the masters of the classroom, so that students can practice in a pleasant and relaxing environment as the main body, and improve students' interest in learning. The goal of the research is to find suitable classroom teaching methods for students and develop the process design of the applicable optimal combination analysis mode.

3. Research methods and experiment analysis
According to the current situation and trend development of classroom teaching, an advanced summary of several currently commonly used teaching methods (Zhang Renjia, 2014) (Lin Jincai, 2018)[4-5], the most used by teachers as Case-reference method…etc, the students participating in the class voted for the Case-reference method as the main teaching method. The specific research, teaching method and process design, result analysis and teaching reflection, its structure and process steps are displayed in Figure 1.

![Figure 1. Study structure and process steps.](image)

3.1. Taguchi method
Use Case-reference method for classroom learning. After completing the course, use the course learning results to design and develop an optimized combined learning model, and continue to improve and promote the teaching so that the research and development results can be applied to more students.

Taguchi Experimental design method (Li Huihuang, 2011) (Sun Jung-Hung, 2012) is developed by Dr. Genichi Taguchi of Japan in 1949 to establish the concept of product quality[6-7]. The Taguchi
The experimental design method is an experimental design method based on the Taguchi orthogonal array and the quality loss function, and regulates these two parameters to achieve the desired quality of design quality. The goal of Taguchi method design is to minimize the influence of the factors of experimental interference. This method has large flexibility, less experiment time, easy experiment configuration and simple analytical method. Due to the above advantages, the experimental method is rapid in various countries. Popularization, there are many research topics in the academic circles and industries at home and abroad that use the Taguchi method (Chen Zhaojun, 2006)[8]. Taguchi's experimental design process is organized as follows:

Set the quality characteristics for the problem. Generally speaking, the quality characteristics are divided into small expected value, high expected value and expected value targets. Different quality characteristics derive different quality characteristics S/N (Signal to noise ratio). The quality characteristic used in this study is a characteristic with a large expected value, and its characteristic value is a positive value LSL (Lower specification limit). The larger the value, the better the characteristic is called the large quality characteristic (such as the semester of this study). The total average score and average class ratio are non-negative values with a minimum of 0, and the larger the score, the better. Such quality characteristics have their S/N ratio formula, as in equation (1), "yi" is the i-th quality characteristic (the total semester total score or attendance rate of the students in the group), and n is the number of materials (number of students in the group).

\[
S/N = -10 \left( \log \frac{\sum_{i=1}^{n} \frac{1}{y_i^2}}{n} \right)
\]

At the end of the period, the total average score and average class ratio of the 9-member semester were counted, and the orthogonal array was configured by the Taguchi experimental method for experimental design. The experiment of configuring the orthogonal-table is to use the partial factorial experiment in the complete factorial experiment to perform factor and level configuration. The orthogonal array obtains useful statistical information with a small number of experiments, and the orthogonal array is very useful for the purpose of solving the case reference teaching method design experimental analysis. The L9 ("L" is the first character of the Latin-square) is converted into signal to noise ratio, as displayed in Table 1.

|     | W   | X   | Y   | Z   | Score (total average) | class ratio (average) |
|-----|-----|-----|-----|-----|-----------------------|-----------------------|
| 1   | lv1 | lv1 | lv1 | lv1 | 38.02699              | 38.42749              |
| 2   | lv1 | lv2 | lv2 | lv2 | 38.90543              | 38.06180              |
| 3   | lv1 | lv3 | lv3 | lv3 | 38.75537              | 38.88314              |
| 4   | lv2 | lv1 | lv2 | lv3 | 38.81033              | 39.44406              |
| 5   | lv2 | lv2 | lv3 | lv1 | 38.39202              | 39.18464              |
| 6   | lv2 | lv3 | lv1 | lv2 | 37.42445              | 38.21249              |
| 7   | lv3 | lv1 | lv3 | lv2 | 38.47317              | 38.98780              |
| 8   | lv3 | lv2 | lv1 | lv3 | 38.87780              | 38.06180              |
| 9   | lv3 | lv3 | lv2 | lv1 | 38.81431              | 39.37153              |

"1~9": The number of rows in the orthogonal-table is the Num. of experiments, 1~9
"W~Z": The number of columns in the orthogonal-table is the factors, W~Z
"lv1~lv3": The numbers in the orthogonal-table are level value

The four control factor symbols (W, X, Y, Z), respectively, represent four types of teaching cases including digital picture books, study guides, guided tours, and interactive games. Each teaching case is subdivided into three levels (Such as W1 case, W2 case, W3 case).
3.2. Fuzzy logic approach

Fuzzy sets were proposed by LA Zadeh in 1965 (Zadeh, LA, 1965) (Zadeh, LA, 1973)[9-10]. In recent years, there have been examples of applications in many fields. Fuzzy theory includes "fuzzy-sets", "fuzzy-relations", "fuzzy-logic", "fuzzy-control", "fuzzy-measure"...etc. The fuzzy-inference system is a control rule string represented by a series of programming languages such as "IF" and "THEN", and the control action set obtained after fuzzy-inference is applied to the controlled process. The control action set can be regarded as a set of conditional programming languages whose control state language is a set of quantized fuzzy language sets, and finally becomes a set of fuzzy languages such as maximum, large, medium, small, and minimum. In general, the construction process of fuzzy-inference system is often divided into fuzzy, fuzzy rule-base, fuzzy database, and defuzzification(Li Yunzhong, Wang Xiaoyu, Su Muchun, 2012)(Wu Bo-Wen, 2020)[11-12], its basic structure, as shown in the Figure 2.

At the beginning, the fuzzy system first converts the information input from the outside world into the input fuzzifier information that the fuzzy control system can receive. Therefore, to make it fuzzy, the input value must be mapped by the membership function to obtain the corresponding ownership. Habitually, the fuzzifier magnitude is defined between 0 and 1. This study uses “triangular shape” in the fuzzy set membership function, as in equation (2).

\[
\mu_A(\theta, \beta, \delta) = \begin{cases} 
0 & x \leq a \\
\frac{x-a}{b-a} & a \leq x \leq b \\
\frac{c-x}{c-b} & b \leq x \leq c \\
0 & c \leq x 
\end{cases}
\]

Figure 2. Fuzzy system inference process structure.

From the fuzzy rule database in Table 2, the combined 9 rules are listed as follows: Rule1–9:

Table 2. Fuzzy rules.

| Fuzzy rules |
|-------------|
| Rule1       | If [Score(total average) is S] and [Class ratio (average) is S] then [MPCI is S] |
| Rule2       | If [Score(total average) is S] and [Class ratio (average) is M] then [MPCI is SM] |
| Rule3       | If [Score(total average) is S] and [Class ratio (average) is L] then [MPCI is ML] |
| Rule4       | If [Score(total average) is M] and [Class ratio (average) is S] then [MPCI is SM] |
| Rule5       | If [Score(total average) is M] and [Class ratio (average) is M] then [MPCI is M] |
| Rule6       | If [Score(total average) is M] and [Class ratio (average) is L] then [MPCI is ML] |
| Rule7       | If [Score(total average) is L] and [Class ratio (average) is S] then [MPCI is M] |
| Rule8       | If [Score(total average) is L] and [Class ratio (average) is M] then [MPCI is ML] |
| Rule9       | If [Score(total average) is L] and [Class ratio (average) is L] then [MPCI is L] |
After successfully constructing the structure of the fuzzy system's rule-base and database, you can use MATLAB's built-in Fuzzy-toolbox to execute program compilation, such as fuzzy rules, fuzzy rule databases, input and output variables... etc.

Nine sets of normalized data are substituted into MATLAB Fuzzy-toolbox and set as input parameters. After nine calculations are performed by the fuzzy rule library and finally defuzzification, nine sets of MPCI output can be obtained, as shown in Table 3.

Table 3. MPCI values.

|   | W     | X     | Y     | Z     | Score (total average) | Class ratio (average) | MPCI (value) |
|---|-------|-------|-------|-------|-----------------------|-----------------------|--------------|
| 1 | lv1   | lv1   | lv1   | lv1   | 0.41                  | 0.26                  | 0.373        |
| 2 | lv1   | lv2   | lv2   | lv1   | 1.00                  | 0.00                  | 0.500        |
| 3 | lv1   | lv3   | lv3   | lv3   | 0.90                  | 0.59                  | 0.695        |
| 4 | lv2   | lv2   | lv1   | lv3   | 0.94                  | 1.00                  | 0.866        |
| 5 | lv2   | lv3   | lv1   | lv2   | 0.65                  | 0.81                  | 0.662        |
| 6 | lv3   | lv1   | lv2   | lv2   | 0.00                  | 0.11                  | 0.165        |
| 7 | lv3   | lv1   | lv3   | lv2   | 0.71                  | 0.67                  | 0.627        |
| 8 | lv3   | lv2   | lv1   | lv3   | 0.98                  | 0.00                  | 0.486        |
| 9 | lv3   | lv3   | lv1   | lv2   | 0.94                  | 0.95                  | 0.800        |

Refer to the configuration L9 (as shown in Table 1), and average the four MPCI values (W, X, Y, Z) of the same level in Table 3 respectively. Taking the W factor as an example, the explanation is as follows:

The average MPCI of W factor Num.1~3 is calculated as follows:

\[
(((0.373+0.500+0.695)/3)=0.5227
\]

Num.4~6 of W factor is calculated as follows:

\[
(((0.866+0.662+0.165)/3)=0.5643
\]

Num.7~9 of W factor is calculated as follows:

\[
(((0.627+0.486+0.800)/3)=0.6377
\]

The rest of the X, Y, Z factors, and so on, sequentially calculate the MPCI value for each factor (W, X, Y, Z) three levels of MPCI response table, as shown in Table 4. The Range column is the difference between the maximum response values (Max. – Min.). The greater the difference between the response values, the greater the factor contribution.

Table 4. MPCI response values.

|   | W     | X     | Y     | Z     |
|---|-------|-------|-------|-------|
| lv1| 0.5227| 0.6220| 0.3413| 0.6117|
| lv2| 0.5643| 0.5493| 0.7220| 0.4307|
| lv3| 0.6377| 0.5533| 0.6613| 0.6823|

Max. - Min. 0.1150 0.0727 0.3807 0.2517

Rank (value) 3 4 1 2

After calculating the MPCI response table, MPCI variability analysis (ANOVA) can be used to find out the factors that have a significant influence on the quality characteristics, and calculate the sum of squares (Sum of squares), degrees of freedom (DOF), and variance. (Variance) and contribution rate (Contribution). The contribution rates of four factors (W, X, Y, Z) are: Factor W (5.3183%), Factor X (2.6179%), Factor Y (65.6299%), and Factor Z (26.4339%), as shown in Table 5.
Table 5. ANOVA-MPCI.

| Factor | Sum of squares | DOF | Variance | Contribution (%) |
|--------|----------------|-----|----------|------------------|
| W      | 0.0203         | 2.0000 | 0.0102 | 5.3183 |
| X      | 0.0100         | 2.0000 | 0.0050 | 2.6179 |
| Y      | 0.2510         | 2.0000 | 0.1255 | 65.6299 |
| Z      | 0.1011         | 2.0000 | 0.0505 | 26.4339 |
| Total  | 0.3824         | 8.0000 | 0.0478 | 100.0000 |

After analysis by ANOVA, it is found that Factors Y and Z have the most obvious contribution. Adjusting Y and Z can quickly converge to the quality characteristics represented by the target value, which can also make the quality of teaching method and process design better. The influence of Factors W and X is relatively insignificant, and its proportion can be reduced in the teaching method and course design to effectively improve the teaching quality of the combination. The optimized combination case corresponding to the MPCI index obtained by the multi-objective optimization method is W³ X¹ Y² Z³.

4. Conclusion and suggestion

4.1. Conclusion

Summarizing the contents of the above chapters, the contribution and novelty of this paper are listed as follows:

(1) Combination of theory and experiment
   (a) The study method is the Taguchi experiment and the rules of fuzzy theory, and the orthogonal-table (L9) is configured to calculate the score (total average) and class ratio (average) of the students in each group to calculate the signal to noise ratio of the quality and normalize the conversion. Then the fuzzy-inference system can be implemented.
   (b) Fuzzy rules are written with MATLAB Fuzzy-Toolbox, and a fuzzy inference system is created, and the fuzzy database, fuzzy step and fuzzy controller are used. Derive a comprehensive multi-function indicator MPCI, and perform ANOVA statistical analysis on the MPCI response table to obtain an optimized combination of factors and levels.
   (c) Taguchi experimental design is a reliable experimental theory. The orthogonal-table (L9) can greatly reduce the number of experimental designs without losing the accuracy of experimental results. And a new application combining the fuzzy system has been developed using precise experimental procedures. The obtained teaching method and process design optimization combined model, the research results can provide teachers with continuous improvement of teaching quality and advanced research of scientific researchers.

(2) R&D concept innovation and creativity

The research and development process needs to think about and overcome the three difficult problems. The analysis is as follows:
   (a) How to reduce the number of analysis data sets, and can achieve the validity of analysis and verification. This paper adopts the Taguchi orthogonal-table experimental design method, and the normal analysis data is 34 groups of 81 groups (4 factors, 3 levels). After reducing the number of analysis data to 9 sets of analysis data through the L9 orthogonal-table, it is very suitable for the group learning method of practical courses (If every group of 2~5 people is used as an example, the class with a total number of students between 20 and 65 can be applied.).
   (b) How to convert qualitative data into quantitative and effective evaluation indicators. This paper uses fuzzy theory to divide the total average score and average class ratio of the semester into three grades (large (L), medium (M), Small (S)), as input, after fuzzy rules and fuzzifier operations, you can get 9 sets of quantitative evaluation indicators (MPCI). According to this indicator, the optimal combination of teaching process design is selected to continuously optimize the teaching and course content.
This study finds a course design principle of teaching method textbooks, which can combine the above two technologies to develop an innovative analysis model that can be used and can be replicated. This study found in the literature discussion that the case design of the case reference teaching method, the high acceptance of students and the effective combination of Fuzzy-Taguchi theory, is very suitable for the development of this innovative analysis model. This research also takes advantage of the advantages of the case-based teaching method, allowing students to learn more interactively and achieve a student-centered teaching situation, so that students can truly return their thoughts to the classroom and enhance the substantive effects of teaching.

4.2. Recommendations

Although this paper successfully developed the optimal combination analysis model of instructional design, it can improve the teaching design and improve the teaching quality. However, there are still many quality factors that affect the teaching effectiveness. After that, more different quality factors or new best research can be used. The combined analysis model is used for experimental analysis to achieve the goal of continuously improving the quality of teaching.

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