Application of AHP Based on Mathematical Operational Research in Teaching Evaluation System

Xing Li, Xiujin Mo*

Department of Mathematics and Information Science, Guangxi College of Education, Nanning, China

*Corresponding author e-mail: 83959142@qq.com

Abstract. Based on the AHP of operational research, this paper studies and analyzes the evaluation indicator of Blending Learning quality, and constructs a set of evaluation system by sorting out the weight calculation, including three first-level indicators and ten second-level indicators. The judgment matrix is used to check the consistency of the ranking of each indicator. The consistency test values of the four judgment matrices are: 0.0370/0.0000/0.0163/0.0370, which means acceptable. Among them, the weight of problem inquiry, creative guidance and communication display is about 0.32. This is very in line with the characteristics of Blending Learning classroom and can give full play to students' initiative and build ability. This study provides theoretical reference and practical guidance for Blending Learning.

Keywords: Analytic Hierarchy Process; Judging Matrix; Blending Learning; Weight; Evaluation System.

1. Introduction

With the rapid development of information technology and educational technology, the teaching idea adapted to the new technology environment is constantly updated and reformed. Since the blending learning model was put forward around 2000, it has been developed and practiced in the past two decades, and has become the mainstream teaching mode to adapt to the new technological environment. A total of 13439 documents were searched on CNKI with "blending learning" as the keyword (as of August 8, 2020). Behind such a large amount of research, there is a lack of corresponding teaching evaluation system research. On CNKI, only 758 results (as of August 8, 2020) were searched with "blending teaching + teaching evaluation" as the keyword. Among these results, most of the research focuses on the construction of the teaching model itself and the evaluation of the students' learning effect [1]. However, there are only 4 papers (in the top 100 cited literatures) which take the teaching quality evaluation system of blended learning as the research object. Through the study of these literatures, it is found that the research on the evaluation system of mixed teaching quality is still in the macro, exploratory and general research stage [2]. The following problems still need further study and solution: first, the characteristics and advantages of blended learning should be reflected in the evaluation indicator. Second, different types of courses should have different evaluation indicators and weights. Third, the evaluation object of evaluation indicator should be more specific and qualified.
The construction of a set of targeted, concrete and operable indicator evaluation system for blending learning will help to supervise and improve the quality of blending learning.

2. Research overview

2.1. Blending learning evaluation system of digital design courses
The course of digital design is a course that combines computer with other subjects and uses computer to assist design. The blending learning method emphasizes taking students as the main body, teaching as the service, combining online with offline and reasonable selection of different teaching methods. These ideas are very consistent with the teaching characteristics of digital design courses. Therefore, in this kind of course, the blended learning mode is generally adopted, and their teaching mode has strong commonality. Compared with other types of courses, such as theoretical teaching, learning inquiry, there are great differences. The research on the blended learning evaluation system of digital design courses is strongly targeted.

2.2. Classroom teaching effect of blending learning
Blended learning is divided into two main stages - online student self-study stage and offline classroom teaching stage. The teaching mode of the two stages should have different evaluation standards [3]. The evaluation system of online course resources for digital design courses has been described in our preliminary work. The research content of this paper is the evaluation indicator of offline classroom teaching quality in blended teaching.

2.3. Method for constructing evaluation indicators
Our team has built a network teaching platform for eight digital design courses, and based on this, we have carried out four semesters of mixed teaching practice and formed a more adequate teaching practice experience and teaching data. At the same time, we also studied a large number of mixed teaching courses and related literature, carried out expert consultation and questionnaire survey on students, teaching teachers and researchers, and conducted reliability and validity analysis on the feedback data. Based on these studies, we have obtained 13 evaluation indicators, of which three are level I indicators and ten are level II indicators.

2.4. Method for constructing evaluation indicators
The analytic hierarchy process (AHP) was formally put forward by the American operational research T.L.saaty. It refers to the decision method that decomposes the elements related to decision into goals, criteria, schemes and so on, and carries out qualitative and quantitative analysis on this basis. In the field of education, many experts use AHP to study the teaching evaluation system [4][5]. When using AHP to construct a system model, it can be divided into four steps: 1. Establish the hierarchical structure model. 2. The judgment matrix is constructed. 3. Hierarchical single ranking and its consistency test. 4. Hierarchical total ranking and its consistency test. Our study follows the modeling steps of AHP, and finally calculates the weights of each indicator.

3. Research implementation

3.1. Evaluation system and establishment of indicators
There are generally three links in the classroom teaching process under blending learning mode of digital design courses: the first is the self-learning effect test link, which supervises and tests the online learning effect to test the students' mastery of basic knowledge and skills. The second is inquiry learning and creative design, which is the core link of classroom teaching, to exercise students' flexible use of knowledge and skills and to build the ability to solve problems. The third is the work display and exchange summary, which can stimulate students' learning enthusiasm and build their cooperation ability and summarize and extend the knowledge and skills of this lesson [4]. This kind of evaluation
index for teaching links has stronger operability in the evaluation of class hours, and has a good guiding role in teaching design. Corresponding to the three first level indicators, three, four and three second level indicators are respectively established. The structure model of the whole evaluation system is shown in Table 1.

**Table 1.** The structure model of classroom teaching effect evaluation of blending learning

| Level I indicator                  | Level II indicator                  | Evaluation criteria                                                                 |
|-----------------------------------|-------------------------------------|--------------------------------------------------------------------------------------|
| Autonomic learning and effect testing A | Test method A1                      | Test students' self-study completion before class and form homework feedback to students |
|                                   | Homework review A2                  | Introduce the content of course study and point out the advantages and disadvantages  |
|                                   | Consolidation of key knowledge A3   | Emphasize the presentation of important basic knowledge of the course                 |
| Inquiry Learning and creative design B | Problem inquiry B1                 | Further explore the expansion or comprehensive use of knowledge and skills             |
|                                   | Creative guidance B3                | Teachers design themes to guide students how to use technology to achieve creativity  |
|                                   | Creative practice B3                | Through guidance, communication, inquiry, students complete the theme works            |
|                                   | Platform conditions B4              | Fully provide the platform, resources and means needed to complete the work           |
| Work display, communication and summary C | Evaluation method C1              | Establish a reasonable evaluation mechanism for students' finished works               |
|                                   | Communication display C3            | Students display excellent works, communicate fully, collaborate and advance together  |
|                                   | Summary of comments C3              | Summarize the knowledge of this lesson and expand the relevant knowledge and skills    |

3.2. **Construct pairwise comparison judgment matrix**

In this paper, the comparison standards of 1, 3, 5, 7, 9 are adopted, which represent the same important, slightly important, relatively important, very important and absolutely important. In the design of the questionnaire, we take into account the comparative evaluation methods, such as the length of time to complete the indicators, the necessity of indicators, the size of the impact on students’ ability in all aspects, the degree of tedious operation, etc. Based on these comparison methods, reliability and validity analysis, some indicators which have little influence and are not easy to compare are eliminated. Therefore, in the formed judgment matrix, the values obtained are between 1, 3 and 5. Finally, the target matrix O matrix (blended learning classroom teaching effect) is shown in Figure 1, and the matrix A (autonomous learning effect test), B matrix (inquiry learning and creative design), and C matrix (work display and communication summary) are shown in Figure 2.
Figure 1. Target layer indicator matrix

\[
A = \begin{bmatrix}
   1 & \frac{1}{3} & 3 \\
   1 & 1 & 5 \\
   \frac{1}{3} & \frac{1}{5} & 1
\end{bmatrix}
\]

Figure 2. Indicator matrix of the criterion layer

\[
A = \begin{bmatrix}
   A_1 & A_2 & A_3 \\
   1 & 1 & \frac{1}{3} \\
   1 & 1 & \frac{1}{3} \\
   3 & 3 & 1
\end{bmatrix}
\]

\[
B = \begin{bmatrix}
   B_1 & B_2 & B_3 & B_4 \\
   1 & \frac{1}{3} & \frac{1}{3} & 3 \\
   1 & 1 & \frac{1}{3} & 3 \\
   \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & 1
\end{bmatrix}
\]

\[
C = \begin{bmatrix}
   C_1 & C_2 & C_3 \\
   1 & \frac{1}{5} & \frac{1}{3} \\
   5 & 1 & 3 \\
   3 & \frac{1}{3} & 1
\end{bmatrix}
\]

Taking A matrix as an example, A1, A2, A3 are the importance of the guidelines to the objectives, while aij is Ai:Aj, i.e. the importance ratio of Ai to Aj. And the matrix is positive and inverse.

3.3. Consistency testing and hierarchical ordering

Whether the index in the matrix is reasonable depends on the consistency of the importance ranking of each index. For a strictly coherent array, aij*ajk=aik should be satisfied. However, the judgment matrix constructed by subjective judgment is impossible and unnecessary to obey this strict consistency. For the inconsistency, we still think it is acceptable as long as within the allowed range. Saaty and others have suggested a definition of consistency. The eigenvector corresponding to the maximum eigenroot of the judgment matrix A is normalized (so that the sum of the elements in the vector is equal to 1) and recorded as W. In the case of computer calculation, it is suitable for power method, which is a stepwise iterative method. After several iterations, according to the specified accuracy, the maximum eigenvalue of the judgment matrix A and its corresponding eigenvector are obtained. W element is the ranking weight of the relative importance of the same level factor to the previous level factor. The weight can be used to measure the importance of the index.

Since the continuity of the largest eigenvalue \( \lambda \) of a matrix depends on aij, the more \( \lambda \) is larger than n of n-order reciprocal matrix, the more serious the inconsistency of matrix A. The eigenvector corresponding to the maximum eigenvalue \( \lambda_{\max} \) is used as the weight vector of the influence degree of the compared factors on the upper factors. The greater the degree of inconsistency, the greater the judgment error. Therefore, the \( \lambda^{-n} \) size can be used to measure the inconsistency of matrix A.

Definition of consistency indicator: \( CI = (\lambda_{\max} - n)/(n - 1) \). If the CI is greater, the consistency is worse. To measure the size of CI, 500 random matrices are calculated CI, their mean values are calculated, and random consistency indexes are constructed RI, and consistency ratio CR=CI/RI are defined. consistency is considered acceptable when CR<0.1. According to the above formula, the weight order of each level is calculated, as shown in Table 3, and the consistency of each matrix is calculated as shown in Table 2.
Table 2. Matrix consistency

| Judging matrix | O   | A   | B   | C   |
|----------------|-----|-----|-----|-----|
| Consistency    | 0.0370 | 0.0000 | 0.0163 | 0.0370 |
| Acceptable or not | Acceptable | Acceptable | Acceptable | Acceptable |

3.4. Hierarchical total sorting

Calculating the scale of relative importance (also called weight vector) of all elements to the highest level (total target) in the same level is called hierarchical total ranking. The steps of hierarchy total ranking are as follows: (1) calculating the weight vector of the relative importance of all factors at the same level to the highest level is carried out from top to bottom layer by layer; (2) The weight vector of nk-1 elements relative to the total target on layer k-1 has been calculated \( w^{(k-1)} = (w_1^{(k-1)}, w_2^{(k-1)}, \ldots, w_n^{(k-1)})^T \); (3) Layer k has a \( n_k \) element. Their single criterion weight vector for an element \( j \) the previous level (layer \( k-1 \)) is \( p_j^{(k)} = (w_1^{(k)}, w_2^{(k)}, \ldots, w_n^{(k)})^T \) (For the corresponding \( w_{ij} \) which is not dominated by the \( j \)-th element in \( k-1 \) layer, the value of \( w_{ij} \) is 0); (4) Weight vectors relative to total target at layer \( k \) \( w_k = (p_1^{(k)}, p_2^{(k)}, \ldots, p_{n_k}^{(k)})w^{(k-1)} \) According to the calculation method, the weight table of evaluation effect of mixed teaching classroom teaching is obtained, as shown in Table 3.

Table 3. Evaluation weight of teaching effect in blended teaching

| Target layer | Criteria layer | Criteria layer weight | Indicator layer | Signal ranking of weights | Total ranking of weights |
|--------------|----------------|-----------------------|-----------------|--------------------------|-------------------------|
| Evaluation on classroom teaching effect of blended teaching | Autonomic learning and effect testing | 0.2583 | Test method | 0.2000 | 0.0517 |
| | | | Homework review | 0.2000 | 0.0517 |
| | | | Consolidation of key points | 0.6000 | 0.1550 |
| | Inquiry Learning and creative design | 0.6370 | Problem Inquiry | 0.1998 | 0.1273 |
| | | | Creative guidance | 0.1998 | 0.1273 |
| | | | Creative practice | 0.5222 | 0.3327 |
| | Work display, communication and summary | 0.1047 | Platform conditions | 0.0781 | 0.0497 |
| | | | Evaluation methods | 0.1047 | 0.0110 |
| | | | Communication and display | 0.6370 | 0.0667 |
| | | | Evaluation and summary | 0.2583 | 0.0271 |

It can be seen from Table 3 that creative practice has the highest weight (0.3327), which accords with that in the classroom teaching of digital design courses, hands-on creative practice is the first element, and it can also best reflect teachers' guiding ability and guiding ability to students. However, some indicators, such as detection method, evaluation method, evaluation method and platform condition, have lower weight (The additive weight of the three items is only about 0.1). Although technology is the basis of ensuring classroom teaching activities, it is easy to operate because teachers are more proficient in information technology and use network tools to carry out these activities. However, the more important aspects of students' ability construction, such as problem inquiry, creative guidance and
communication display, have higher weight (The additive weight of the three items is about 0.32). This is very in line with the characteristics of Blending Learning classroom and can give full play to students' initiative and build ability.

4. Conclusions
This paper uses the analytic hierarchy process (AHP) of operational research as analytical method to analyze the blending learning of digital design courses. We analyze it through four steps. The first step is to establish a hierarchical structure model, which is guided by teaching links, based on the implementation of teaching activities and centered on the construction of students' ability. The second step is to construct the judgment matrix, whose values are derived from the teaching practice real number, expert discussion and teacher-student questionnaire feedback. In the third step, the hierarchical single row and its consistency test are carried out. After the consistency calculation, each judgment matrix meets the consistency requirements and can be used as an indicator. Finally, the total ranking of the levels is carried out, and the weight of each indicator is calculated. Through the analysis of the weight, it is considered that it is in line with the characteristics of blending learning, and is in line with the teaching practice of digital design courses. Through this evaluation system, the classroom teaching effect of blending learning is accurately measured, and it also provides a useful reference for the teaching design and practice of blending learning.

Acknowledgments
2017 Guangxi Vocational Education Teaching Reform Research Project (GXGZJG2017B165)

References
[1] Yang Geyao. Literature review and Prospect of teaching evaluation under blending learning mode, J. Higher Education Forum, 02 (2019) 64-67
[2] Yang Hao, Construction and application practice of mixed teaching quality evaluation indicator system in higher vocational colleges, J. Chinese Vocational and Technical Education, 11 (2019) 69-75
[3] Han Xiaoling, Xu Juan, Construction of evaluation indicator system for curriculum resources of blended learning, J. Modern Educational Technology, 12 (2018) 34-40
[4] Qiu Wenjiao, Zhao Guang, Lei Wei, Construction of evaluation indicator system of inquiry based classroom teaching in Colleges and Universities Based on analytic hierarchy process (AHP), J. Research in Higher Education of Engineering, 06 (2016) 138-143
[5] Zhao Xinrui, Zhou Yuqing, Evaluation of MOOC teaching quality of college physics based on fuzzy comprehensive evaluation method J. Research in Higher Education of Engineering, 01 (2019) 190-195
[6] Li Yong, Easy to master flipped classroom, first edition, Tsinghua University, Beijing, 2018