Identifying critical factors affecting the project-based teaching mode, based on a fuzzy DEMATEL method

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ABSTRACT: Identifying the critical factors that affect the project-based teaching mode has played an important role to improve the teaching effect of the mode. The fuzzy set theory and DEMATEL method are used to analyse the attributes of each factor relevant to the mode and the relationships among these factors. In this research project, teacher and student dimensions of four critical factors have been identified. These are the *coverage of the main knowledge points*, *development difficulty*, *evaluation of project's phase results* and *students' performance in proceeding curricula*.

INTRODUCTION

The project-based teaching mode is a teaching method developed on the basis of constructivism theory [1]. It is also advocated by the CDIO concept [2][3]. Different from the traditional teaching mode, the project-based teaching mode has the following features: 1) it is student-centred; 2) it is the combination of the teaching contents and actual projects; and 3) it provides students with exposure to the project development process.

In the project-based mode, the students can combine theory with practice of the projects, through full participation in several stages of the project development. The mode is particularly helpful for improving students' ability to analyse and resolve problems [4]. Because of these advantages, the project-based mode has attracted extensive attention and is widely used among teaching practitioners.

However, there are some problems in the application of this mode, such as a different teacher may choose different projects to arrange teaching activities. Therefore, the difference of the teaching effect is relatively large.

Another example is that the same teaching project carried out with different students, may lead to a completely different effect with a great difference. Therefore, it is important to identify the critical factors that have an impact on the effect of project-based teaching mode.

LITERATURE REVIEW

Lin [5] and Lin [6] applied the project-based teaching mode to database theory, software engineering and other curricula. In their studies, the factors that affected the project-based teaching mode were analysed from the process of projects; namely, the project's development difficulty and the project work load, and other factors were proved to have an important influence on the effectiveness of the project-based teaching mode.

Zhao [7] and Zhu [8] have analysed the role that the teachers should play in the project-based teaching mode from the aspect of the teacher. They hold a viewpoint that the teacher should control the project schedule and assess the project's phase results to improve the effect of the project-based teaching mode. Meanwhile, they agreed that the teacher's experience also had an important influence on this mode.

Dong [9] and Jiang [10] analysed the factors that affect the effectiveness of the project-based teaching mode from the perspective of students. In their studies, the students' performance in forward curricula and mutual assistance among students were proved to have an importance influence on the effectiveness of the project-based teaching mode.

Form the above literature, one can find that most of the current research on the project-based teaching mode is from one of several perspectives. These research projects proposed the factors that affect the project-based teaching mode from the aspect of the project, teacher and student. However, what are the critical atributes in these factors? How can they be identified? For these problems, the current literature lacks systematic research.

INFLUENCE FACTORS

Based on above literature, the influence factors of the project-based teaching mode can be summarised from three dimensions: project, students and teachers. The factors are as follows: coverage of the main knowledge points (C_1), development difficulty (C_2), workload (C_3), teacher's experience (C_4), assessment of project's phase results (C_5), project schedule control (C_6), students' performance in forward curriculums (C_7) and mutual assistance among students (C_8). The factors are shown in Table 1.

Table 1: The influence factors of the project-based teaching mode.

Dimensions	Factors
Project dimension	Coverage of the main knowledge points (C_1)
	Development difficulty (C_2)
	Workload (C_3)
Teacher dimension	Teacher's experience (C_4)
	Assessment of project's phase results (C_5)
	Project schedule control (C_6)
Students dimension	Students' performance in forward curriculums (C_7)
	Mutual assistance among students (C_8)

METHODOLOGY

For the factors included in Table 1, 10 teachers and 15 students from Jiang Xi University of Science and Technology were invited as experts to evaluate the mutual influence between the factors. In the process of the evaluation, the experts tended to use linguistic variables rather than exact values to evaluate the degree of influence between factors. Consequently, the evaluation results by the experts are processed numerically by triangular fuzzy number (TFN). Then, the DEMATEL method is used to analyse the relationships between the factors on the basis of above results. Finally, the critical factors of the project-based teaching mode can be determined by analysing the prominent value of each factor.

Precise Processing of Experts' Linguistic Variables

According to the rules presented in Table 2, the evaluation results of 25 experts can be converted to the corresponding triangular fuzzy numbers. It can be represented by $Z_{ijk} = (l_{ij}^k, m_{ij}^k, r_{ij}^k)$, where, $k = 1,2,3,...,25, i(j) = 1,2,3,...,8$.

Table 2: Corresponding relationships between linguistic variables and triangular fuzzy numbers.

Linguistic variables	Triangular fuzzy number (TFN)
N (no influence)	(0, 0.1, 0.2)
L (low influence)	(0.2, 0.3, 0.4)
M (moderate influence)	(0.4, 0.5, 0.6)
H (high influence)	(0.6, 0.7, 0.8)
VH (very high influence)	(0.8, 0.9, 1.0)

According to the following steps, the TFN of the experts' evaluation can be transformed into the exact numerical value.

Step 1: According to Equation (1), the TFN of the experts' evaluation can be standardised:

$$xl_{ij}^k = \frac{l_{ij}^k - \min\limits_{1\le k\le 25} l_{ij}^k}{\max\limits_{1\le k\le 25} r_{ij}^k - \min\limits_{1\le k\le 25} l_{ij}^k},\ xm_{ij}^k = \frac{m_{ij}^k - \min\limits_{1\le k\le 25} l_{ij}^k}{\max\limits_{1\le k\le 25} r_{ij}^k - \min\limits_{1\le k\le 25} l_{ij}^k},\ xr_{ij}^k = \frac{r_{ij}^k - \min\limits_{1\le k\le 25} l_{ij}^k}{\max\limits_{1\le k\le 25} r_{ij}^k - \min\limits_{1\le k\le 25} l_{ij}^k} \quad (1)$$

Step 2: According to Equation (2), the left and right standard value can be calculated as follows:

$$xls_{ij}^k = \frac{xm_{ij}^k}{1 + xm_{ij}^k - xl_{ij}^k},\ xlr_{ij}^k = \frac{xr_{ij}^k}{1 + xr_{ij}^k - xm_{ij}^k} \quad (2)$$

Step 3: According to Equation (3), the left and right values are converted to the total standard values:

$$x_{ij}^{k} = \frac{xls_{ij}^{k}(1 - xls_{ij}^{k}) + xrs_{ij}^{k} xrs_{ij}^{k}}{1 - xls_{ij}^{k} + xrs_{ij}^{k}} \tag{3}$$

Step 4: According to Equation (4), the influence value of Factor *i* to Factor *j* from each expert can be calculated as follows:

$$a_{ij}^{k} = \min_{1 \le k \le 25} l_{ij}^{k} + x_{ij}^{k} (\max_{1 \le k \le 25} r_{ij}^{k} - \min_{1 \le k \le 25} l_{ij}^{k}) \tag{4}$$

Step 5: The influence value of Factor *i* to Factor *j* from all experts can be found using Equation (5):

$$a_{ij} = \frac{1}{25} \sum_{k=1}^{25} a_{ij}^{k} \tag{5}$$

Through above steps, the direct influence Matrix A of influence factors of project-based teaching mode can be obtained, where $A = [a_{ij}]_{8\times 8}, i, j = 1,2,3,...,8$, when I = j, $a_{ij} = 0$. The results are shown in Table 3.

Table 3: The direct influence Matrix A of influence factors of project-based teaching mode.

Factor	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	0	0.781	0.691	0.1	0.381	0.5	0.182	0.381
C_2	0.619	0	0.5	0.1	0.381	0.381	0.144	0.344
C_3	0.182	0.381	0	0.1	0.374	0.182	0.1	0.396
C_4	0.5	0.381	0.381	0	0.781	0.781	0.1	0.1
C_5	0.1	0.1	0.1	0.1	0	0.381	0.1	0.256
C_6	0.1	0.1	0.144	0.1	0.5	0	0.1	0.219
C_7	0.456	0.5	0.396	0.1	0.656	0.633	0	0.219
C_8	0.1	0.1	0.1	0.1	0.219	0.144	0.1	0

Measurement of the Relationships between Factors

Based on Matrix A, the relationships between factors can be calculated by DEMATEL method. The steps are as follows:

Step 1: According to Equation (6), Matrix A is normalised to obtain Matrix X:

$$X = A / \max_{1 \le i \le 8} \sum_{j=1}^{8} a_{ij} \tag{6}$$

Step 2: According to Equation (7), the relationships Matrix T among factors is:

$$T = X(I - X)^{-1} \tag{7}$$

Step 3: The sum of columns of Matrix T and sum of rows of Matrix T can be calculated using Equation (8); they can be represented by D_i and R_j

$$D_i = \sum_{j=1}^{8} t_{ij}, \quad R_j = \sum_{i=1}^{8} t_{ij} \tag{8}$$

Then, D_i represents the sum of the influence of Factor *i* on other factors, including a direct and indirect influence. R_j represents the sum of the influence on Factor *j* by other factors. $D_k + R_k$ is called prominence, which is the sum of D_k and R_k. It indicates the importance of Factor *k* among all the factors that influence the effect of the project-based teaching mode.

The larger value of $D_k + R_k$, the more important the Factor *k*. $D_k - R_k$ is called relation, which is the difference between D_k and R_k. When $D_k - R_k$ is positive, Factor *k* tend to be a reason type factor. When $D_k - R_k$ is negative, Factor *k* tend to be an influence type factor. According to Equations (6) and (7), by combing Matrix A, the overall influencing relationship of project-based learning mode can be calculated. The results are shown in Table 4.

Table 4: Aggregation of overall influencing relationship of project-based learning mode.

D		R		D+R		D-R	
Item	Value	Item	Value	Item	Value	Item	Value
C_4	2.432	C_5	2.594	C_1	4.004*	C_{4-}	1.781
C_7	2.407	C_6	2.338	C_2	3.911*	C_7	1.647
C_1	2.393	C_2	1.850	C_5	3.513*	C_1	0.782
C_2	2.061	C_3	1.813	C_6	3.336	C_2	0.211
C_3	1.403	C_8	1.748	C_3	3.216	C_3	-0.410
C_6	0.998	C_1	1.611	C_7	3.168	C_8	-0.995
C_5	0.919	C_7	0.760	C_4	3.083	C_6	-1.34
C_8	0.753	C_4	0.651	C_8	2.501	C_5	-1.675

Note: *represents the factor's value larger than the overall average value 3.342

CONCLUSIONS

From the respect of D-R, it can be found that the D-R of C_4, C_7, C_1 and C_2 are positive, they are reason type factors. The D of C_4 and C_7 are very high, and they are rank first and second in all the factors. Meanwhile, the R of C_4 and C_7 are very low. It means that C_4 and C_7 have a significant influence on other factors, but they are seldom influenced by other factors. For C_1 and C_2, the D of them is relatively high, and the R of them is also relatively high. Thus, C_1 and C_2 have a certain influence on other factors, and they are also influenced by other factors to some extent. On the other hand, the D-R of C_3, C_8, C_5 and C_6 are negative, they are influenced type factors. The R of C_6 and C_5 are very high, but the D of C_6 and C_5 are very low. It means that C_6 and C_5 are easily influenced by other factors, but they are very difficult to affect other factors. The D and R of C_3 are relatively high. Thus, C_3 is influenced by other factors, but also has a certain effect on other factors. The D and R of C_8 are relatively low, so the relationship between C_8 and other factors is relatively distant.

Form the respect of D+R, the values of C_1, C_2 and C_5 are larger than the average value 3.342. It means that C_1, C_2 and C_5 each have an important influence on the project-based teaching mode. Thus, C_1, C_2 and C_5 can be determined as the critical factors to influence the project-based teaching mode. Meanwhile, according to Table 1, it can be found that C_1 and C_2 are critical factors in project dimension, and C_5 is the critical factor in teacher dimension. Therefore, one also needs to identify the critical factor in student dimension. It can be found that C_7 and C_8 are the factors in student dimension. From the respect of D+R, C_7 is much higher than C_8. Therefore, the importance of C_7 is much higher than C_8. From the respect of D-R, C_7 is a reason type factor. The D-R value of C_7 is rank second. It has a significant influence on other factors, and it is a very important factor in the project-based teaching mode. On the other hand, C_8 is an influence type factor. The D-R value of C_8 is very low. It hardly influences on other factors. Thus, C_7 is the critical factor in student dimension.

In the end, the critical factors that affect the project-based teaching mode are as follows: C_1 (*coverage of the main knowledge points*), C_2 (*development difficulty*), C_5 (*evaluation of project's phase results*) and C_7 (*students' performance in forward curriculum*).

In order to improve the effect of the project-based teaching mode, one needs to choose the project that can cover most of the main knowledge point and has a moderate development difficulty as the teaching project at a project level. At the teacher level, attention needs to be paid to evaluation of project's phase results, so as to resolve immediately the problem in teaching process. At the student level, students need to master the knowledge of the forward curriculum that is related to the project.

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