Mode and Effect Evaluation of Classroom Regulation Under Hybrid Teaching Mode in Colleges

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Abstract—Under hybrid teaching mode, teachers often find it hard to control the rhythm of the classroom, and need to sort out the relationship between various elements in the class. To achieve the ideal teaching effect through classroom regulation, this paper explores the mode and effect evaluation of classroom regulation under hybrid teaching mode in colleges. Firstly, the authors preprocessed and extracted features from the data on classroom regulation indices, and explained the training process and steps of the proposed backpropagation neural network (BPNN). Based on fuzzy comprehensive evaluation (FCE), a state evaluation model was established for classroom regulation, and the construction procedure was detailed for the multi-level FCE model. Next, an index system was constructed for the effect evaluation of classroom regulation under hybrid teaching mode in colleges, and the evaluation process was clarified for the classroom regulation effect. Finally, several experiments were carried out to examine the implementation of classroom regulation measures in different periods, and obtain the evaluated effects of classroom regulation.

Keywords—hybrid teaching mode, classroom regulation mode, effect evaluation of classroom regulation

1 Introduction

The classroom is a complex environment of interpersonal relationships between students, teachers, and learning resources in the environment [1-9]. This complex environment is further complicated by the hybrid teaching mode in colleges [10-15]. Ideally, classroom teaching should ensure that students have sufficient time to learn knowledge, and that teacher-student exchanges are on an equal basis [16-18]. In the ecosystem of the classroom, teachers play the role of organizer, guide, and counselor. Whether the teaching effect and goals can be realized depends on the teachers' classroom regulation measures [19-22]. Under hybrid teaching mode, teachers often find it hard to control the rhythm of the classroom. The relationship between various elements in the class must be sorted out to give full play to students' subjectivity, while controlling their behaviors in class. Therefore, it is necessary to investigate and study how to achieve the ideal teaching effect through classroom regulation.

Flipped classroom is a novel type of hybrid teaching method. Starting from the principle of self-regulation, Ng [23] discussed whether flipped classroom is an effective teaching method to improve the formative learning effect of freshmen. Their research involves 73 students participating in teacher education projects. Seufert et al. [24] attempted to test whether the pre-service teachers learning classroom management (CM) assisted by virtual reality (VR) do better in CM than the students learning in the traditional environment. The CM capability development was assessed through self-evaluation and lecturer evaluation, and the learning quality was measured under different learning conditions.

With the recent development of the Internet, cloud computing and big data, more and more smart devices are being introduced to intelligent classrooms [25-28]. Based on OneNet, Shang et al. [29] proposed a novel architecture of intelligent classrooms to realize effective teaching management. Under the architecture, the traditional check-in approach was improved by Bluetooth positioning techniques and mobile terminal devices. The architecture can automatically analyze environmental information in the classroom through sensors, and intelligently adjust the environmental state of the classroom through the cloud platform.

Rain classroom, as a design tool for intelligent classrooms, deeply integrates information technology with traditional teaching to realize hybrid teaching. Through a questionnaire survey on teaching objects, Shen et al. [30] processed the data on the hybrid teaching effect of rain classroom, and analyzed the functions of rain classroom in CM. Amalia and Brata [31] explored the e-learning ability of teachers based on CM. Specifically, a questionnaire survey was carried out on classes in a vocational school. The subjects were randomly sampled from the students and teachers in class 2018/2019 of Malang Vocational School.

Classroom regulation has been studied at home and abroad for a long history. Many scholars have explored the theoretical bases, categories, methods, and strategies of classroom regulation. However, there is no report from an independent research field. To solve the problem, this paper explores the mode and effect evaluation of classroom regulation under hybrid teaching mode in colleges. Firstly, Section 2 preprocesses and extracts features from the data on classroom regulation indices, and explains the training process and steps of the proposed backpropagation neural network (BPNN). Focusing on evaluating the overall state of a course, Section 3 proposes a state evaluation model was established for classroom regulation based on fuzzy comprehensive evaluation (FCE), and details the construction procedure detailed for the multi-level FCE model. Section 4 builds an index system for the effect evaluation of classroom regulation under hybrid teaching mode in colleges, and clarifies the evaluation process for the classroom regulation effect. Finally, several experiments were carried out to examine the implementation of classroom regulation measures in different periods, and obtain the evaluated effects of classroom regulation.

2 Data preprocessing and feature selection

Under hybrid teaching mode in colleges, the classroom regulation indices were selected from three aspects: students, teachers, and learning resources in the environment. The student indices include the students' motivations, interests, initiatives, participation, and self-efficacy of online-offline hybrid learning. The teacher indices include the teachers' organization ability, expression ability, caring ability, cognition ability of learning state, and feedback ability. The indices about the learning resources in the environment include the abundance of learning resources, the functional completeness of the information learning platform, the completeness of the preset teaching scenario for the students, and the classroom learning atmosphere.

The data on the regulation indices in the above three aspects differ in dimensionality. To eliminate the dimensional difference, the original data were normalized by mapping them to the interval of [0, 1], before being used for modeling. Let A_i be the normalized data; A be the original data; A_{max} and A_{min} be the maximum and minimum of historical data, respectively. Then, the normalization and reverse normalization of the index data can be respectively expressed as:

$$A_i^{'} = \frac{A_i - A_{min}}{A_{max} - A_{min}} \tag{1}$$

$$A_i = A_i^{'}\left(A_{max} - A_{min}\right) + A_{min} \tag{2}$$

To reduce the redundancy of the index data and simplify the prediction model for classroom regulation state, this paper puts forward a BPNN based on the mean impact value (MIV) algorithm, and selects the features from the index data, i.e., selects the features for the input parameters for the prediction model for classroom regulation state. Figure 1 shows the topology of the proposed neural network. It can be observed that the proposed BPNN consists of an input layer, a hidden layer, and an output layer, and involves both forward propagation and backpropagation. During forward propagation, the characteristic parameters of the samples are processed by preset rules, and passed from the input layer to the hidden layer. The parameters are further processed by the hidden layer, before being outputted by the output layer. If the network output deviates far from the preset expectation, the data will propagate backward in the network.

Let a be the input data on each index; M_1, M_2, and M_3 be the number of nodes in the input layer, hidden layer, and output layer, respectively; ω_{if} and ω_{fj} be the connection weight between the input layer and the hidden layer, and that between the hidden layer and the output layer, respectively; c be the network output. Then, the training process and steps of the proposed BPNN can be detailed as follows:

Step 1. Let λ_j and ψ_p be the thresholds of the hidden layer and the output layer, respectively; A and C be the input vector and output vector, respectively. Based on A and C, the connection weights, the number of nodes on each layer, as well as λ_j and ψ_p are initialized.

Step 2. A series of inputs $a=(a_1,a_2,...,a_{M1})$ and a series of target samples $c=(c_1,c_2,...,c_{M3})$ are selected, and provided to the proposed BPNN.

Step 3. Suppose $g(a)=1/1+e^{-a}$ is the *Sigmoid* function serving as the activation function of the hidden layer. Then, the input r_j and output b_j of each node in the hidden layer can be respectively calculated by:

$$r_j = \sum_{i=1}^{m} \omega_{if} a_i - \lambda_j \tag{3}$$

$$b_j = g\left(r_j\right), j = 1, 2, .., t \tag{4}$$

Step 4. Let C_p be the output of the output layer; D_p be the response of each node on the output layer. Then, C_p and D_p can be respectively calculated by:

$$C_p = \sum_{j=1}^{t} u_{ij} y_j - \psi_p \tag{5}$$

$$D_p = g\left(K_p\right), p = 1, 2, .., w \tag{6}$$

Step 5. Let ε^l_p and ρ^l_j be the errors of the output layer and hidden layer, respectively. Finding the difference between $c=(c_1,c_2,...,c_{M3})$ and D_p, ε^l_p and ρ^l_j can be respectively calculated by:

$$\varepsilon_p^l = \left(b_p^l - D_p\right) \bullet D_p \left(1 - D_p\right) \tag{7}$$

$$\rho_j^l = \left[\sum_{p=1}^{w} \varepsilon_p \cdot u_{ji}\right] y_i \left(1 - y_i\right) \tag{8}$$

Step 6. Connection weights ω_{if} and ω_{fj} can be respectively corrected by:

$$\omega_{fj}\left(M+1\right) = \omega_{fj}\left(M\right) + \gamma \cdot \varepsilon_p^l \cdot y_j \tag{9}$$

$$\omega_{if}\left(M+1\right) = \omega_{if}\left(M\right) + \phi \cdot \rho_p^l \cdot x_i^l \tag{10}$$

where, p=1, 2, ..., w; j=1, 2, ..., t; $0<x<1$.

Step 7. Thresholds λ_j and ψ_p can be respectively corrected by:

$$\lambda_j\left(M+1\right) = \lambda_j\left(M\right) + \phi \cdot \rho_j^l \tag{11}$$

$$\psi_p\left(M+1\right) = \psi_1\left(M\right) + \gamma \cdot \rho_p^l \tag{12}$$

where, i=1,2,...,m; j=1,2,...,t; $0<\varphi<1$.

Step 8. The next series of index data vectors are selected, and imported to the proposed BPNN. Steps 2-7 are executed iteratively until meeting the termination condition of training.

Step 9. The data on each index are increased and reduced by 15%, producing two new series of input data X_1 and X_2. Then, X_1 and X_2 are imported to the trained BPNN to obtain the predicted values Y_1 and Y_2.

Step 10. Finding the difference between Y_1 and Y_2, the impact variations are averaged to obtain the MIV (Figure 2).

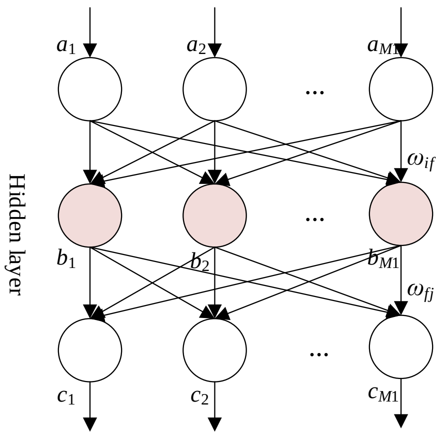

Fig. 1. Topology of the proposed BPNN

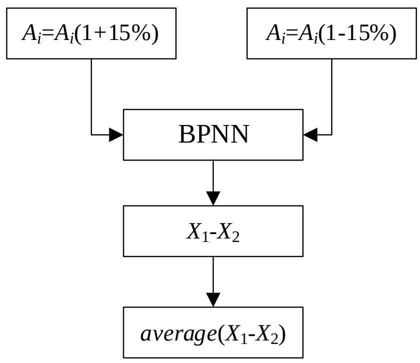

Fig. 2. Solving process of the MIV

For the hidden layer, the hyperbolic tangent function *tansig* was chosen as the activation function: $2/(1+e^{-2a})-1$. For the output layer, the *purelin* function was selected as the activation function: $g(a)=l*a+d$. The Levenberg–Marquardt (LM) algorithm was adopted to train the network. The number of hidden layer nodes can be determined by empirical formulas. Let n and m be the number of nodes in the input layer and the output layer, respectively; k be the number of nodes in the hidden layer; τ be a random number in [0, 10]. Then, we have:

$$k=\sqrt{n+m}+\tau, \tau=1,2,3...,10 \tag{13}$$

3 FCE of classroom regulation state

Under the hybrid teaching mode, the classroom regulation state cannot be fully displayed by predicting a single system state. However, most state prediction models for classroom regulation can only assess a single state of classroom regulation. Focusing on evaluating the overall state of a course, this paper proposes a state evaluation model was established for classroom regulation based on FCE. The model combines multiple classroom regulation indices to objectively assess the overall state of classroom regulation, and identify the defects of classroom regulation mode as early as possible. The construction procedure of the multi-level FCE model is detailed below.

Step 1. The goals, object set $A\{A_1,A_2,...,A_l\}$, index set $V=\{v_1,v_2,...,v_m\}$, and comment set $U=\{u_1,u_2,...,u_n\}$ are determined for the state evaluation of classroom regulation.

Step 2. The fuzzy relationship matrix can be established as:

$$S=\begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_m \end{bmatrix}=\begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{bmatrix}$$

Step 3. The weight of each factor is determined as $X_i=\{x_1^{(i)},x_2^{(i)},...,x_{mi}^{(i)}\}$, where $\sum^{mi}_{p=1}x_p^{(i)}=1$.

Step 4. The FCE matrix is set up as $Y=X\cdot S=(y_1,y_2,...,y_n)$.

Step 5. The classroom regulation state is determined. Following the principle of maximum membership, a state evaluation goal of classroom regulation should be allocated to the class of comment u_l, if $max\{y_1,y_2,...,y_n\}=y_l$.

This paper introduces the parameter deterioration degree to measure how much a classroom regulation index deviates from the normal value. The degree falls in the interval of [0, 1]. Depending on the specific indices, the deterioration degree could be the smaller the better, neutral, or the greater the better. According to their attributes, the selected classroom regulation indices all belong to the class of the greater the better. Let a be the current threshold for a classroom regulation index; a_{max} and a_{min} be the maximum and minimum of the index corresponding to the current threshold, respectively; a_x and a_y be the maximum and minimum of the optimal interval, respectively. Then, the parameter deterioration degree $IG(a)$ of classroom regulation can be calculated by:

$$IG\left(a\right)=\begin{cases} 1, a<a_{min} \\ \dfrac{a_{max}-a}{a_{min}-a_{min}}, a_{min}\leq a\leq a_{max} \\ 0, a>a_{max} \end{cases} \tag{14}$$

4 Effect evaluation model of classroom regulation

Figure 3 presents the flow of effect evaluation of classroom regulation. Firstly, an index system is established for the effect evaluation. According to the index system, the collected index data are preprocessed through the following steps: filling the missing data, computing the index weights, and normalizing the complete index dataset. The preprocessed data can be used to evaluate the effect of classroom regulation.

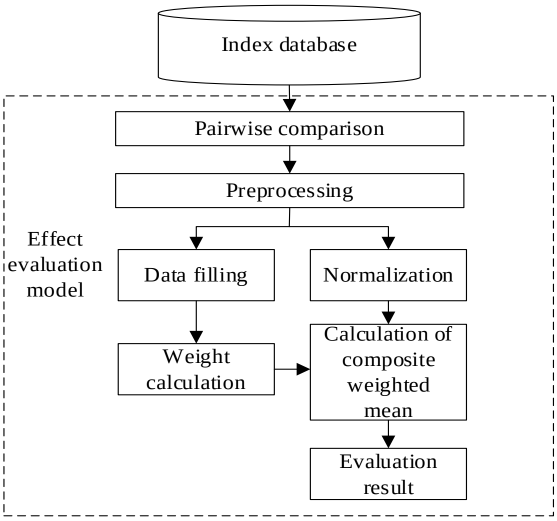

Fig. 3. Flow of effect evaluation of classroom regulation

The effect evaluation model varies with the classroom regulation modes under the hybrid teaching mode in colleges. The following is an introduction to the effect evaluation model related to this research. The proposed index system is as follows:

Layer 1 (classroom regulation mode):

$CRE=\{CRE_1, CRE_2, CRE_3\}$={preset classroom regulation, corrective classroom regulation, mandatory classroom regulation}.

Layer 2 (classroom regulation behaviors):

$CRE_1=\{CRE_{11}, CRE_{12}, CRE_{13}, CRE_{14}\}$={preset classroom teaching environment, raising questions about teaching contents, emphasis on key teaching contents, transformation of teaching activities};

$CRE_2=\{CRE_{21}, CRE_{22}, CRE_{23}, CRE_{24}, CRE_{25}, CRE_{26}\}$={error correction, making evaluation, explaining rules of teaching activities, language hints, walking and pausing, gestures};

$CRE_3=\{CRE_{31}, CRE_{32}, CRE_{33}\}$={named warning, direct order, criticism and punishment}.

The above indices were subjected to pairwise comparisons. Let $\eta_{ij}=(1,2,3,...,m)$ be the importance ratio between index i and index j. Then, the judgement matrix PD can be established as:

$$PD = \begin{bmatrix} \eta_{11} & \cdots & \eta_{1m} \\ \vdots & \ddots & \vdots \\ \eta_{m1} & \cdots & \eta_{mm} \end{bmatrix} \tag{15}$$

By the fuzzy analytic hierarchy process (FAHP), PD can be defined as:

$$PD = \left\{ \eta_{ij} = l \in \left(0.1, 0.2, ..., 0.9\right) \right\} \tag{16}$$

The weight vector of each index can be calculated by:

$$\omega = \left\{ \omega_i = \frac{\sum_j^m \eta_{ij} + \frac{m}{2} - 1}{m\left(m-1\right)} \right\} \tag{17}$$

The rough set theory, which does not rely on any prior knowledge, and applies to small sample mining, was adopted to evaluate the classroom regulation effect. Based on the collected index data, the index weights were calculated, and the index system was simplified. Firstly, the domain of discourse *ES*={index values at different moments} was established for the effect evaluation of classroom regulation, and the decision attribute MP of classroom regulation was set as the state of the network evaluation goal. Let ZY be the positive domain; |*| be the base calculation of the set. Then, the weight of each index *O'* in the index set O can be calculated by:

$$\chi_{O \cdot MP}\left(O'\right) = s_O\left(MP\right) - s_{O-O'}\left(MP\right) = \frac{\left|ZY_O\left(MP\right)\right|}{\left|ES\right|} - \frac{\left|ZY_{O-O'}\left(MP\right)\right|}{\left|ES\right|} \tag{18}$$

Figure 4 shows the calculation flow for effect evaluation indices of classroom regulation. After all the indices were weighed, any index with a weight of zero was eliminated as a redundant index. The weights of the simplified index system were thus obtained, and used to compute the composite weighted average, yielding the evaluated effects of classroom regulation.

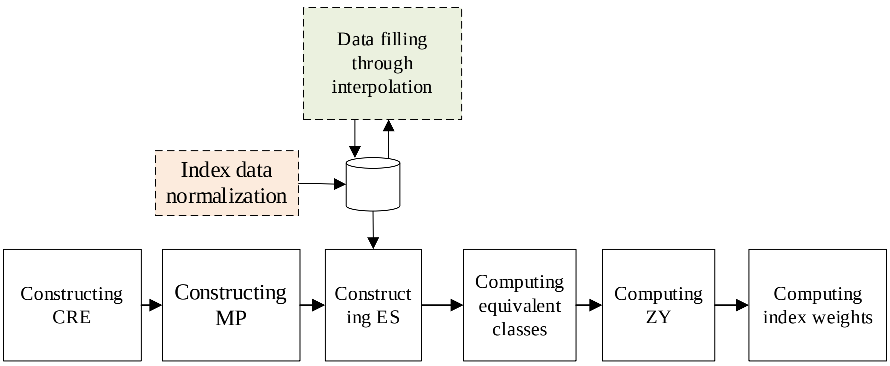

Fig. 4. Flow of index weighting

5 Experiments and results analysis

The descriptive statistics of classroom regulation indices were illustrated on SPSS. Table 1 shows the descriptive statistics of the selected indices looked up by the data viewer.

Table 1. Descriptive statistics of classroom regulation indices

		Number of cases	Minimum	Maximum	Mean	Standard deviation
Hybrid learning	Learning motivations	316	1.1	5.16	3.051	0.9581
	Learning interests	301	1.7	5.02	3.629	0.8475
	Learning initiatives	374	1.3	5.47	3.748	0.9631
	Learning participation	342	1.9	5.26	3.052	0.9744
	Self-efficacy	326	1.3	5.38	3.625	0.9248
Hybrid teaching	Organization ability	308	1.1	5.15	3.147	1.3623
	Expression ability	392	1.7	5.62	3.065	0.9174
	Caring ability	365	1.5	5.94	3.748	0.9620
	Cognition ability of learning state	318	2.6	5.48	3.692	0.8457
	Feedback ability	342	1.2	5.31	3.285	0.8625
Learning resources in the environment	Abundance of learning resources	347	1.4	5.15	4.528	0.8627
	Functional completeness of the information learning platform	362	1.8	5.62	3.194	1.7154
	Completeness of the preset teaching scenario	384	1.6	5.72	3.052	0.9265
	Classroom learning atmosphere	308	1.2	5.48	3.147	0.9528

In terms of students' hybrid learning, the learning initiatives had the highest mean, indicating that that most students recognize the importance of learning to their schoolwork and future development. The learning motivations had the lowest mean, indicating that although the students are aware of the importance of learning, classroom regulation cannot obviously change the learning motivations during hybrid learning. To motivate the students to change their motivations, the teachers are required to play the role of organization and guidance during hybrid teaching.

In terms of teachers' hybrid teaching, the caring ability had the highest mean, indicating that the teachers' emotional and vocal encouragement can improve the students' learning effect. The expression ability had lower mean than the other factors, probably because some teachers ignore the important effect of expression ability on the students' comprehension of key knowledge.

In terms of learning resources in the environment, the abundance of learning resources had the highest mean, indicating that the learning effect improves with the abundance of learning resources. During hybrid teaching, the teachers should prepare lots of online learning resources, which could ensure the smooth implementation of teaching activities. The lowest mean belonged to the completeness of the preset teaching scenario. This issue is often ignored by teachers, who think that the completeness of the preset teaching scenario does not play a key role in learning.

Table 2 lists the frequency of control behaviors in each period of the class. It can be seen that teachers chose different classroom regulation methods in different periods of the two classes. The preset classroom regulation was frequently utilized in the two classes. Corrective classroom regulation was applied most frequently in the latter section of the first class and in the former section of the second class. In these two periods, the teachers tend to impart new knowledge, and the students are very likely to have doubts.

Table 2. Frequency of control behaviors in each period

	[0,20]	**[20,40]**	**[40,60]**	**[60,80]**
Preset classroom regulation	67	49	55	28
Corrective classroom regulation	22	45	43	14
Mandatory classroom regulation	1	3	5	1
Total number of regulations	90	97	103	43
Mean	8.7	9.7	9.3	4.6

Facing all students, the preset classroom regulation enables teachers to create a harmonious and positive learning atmosphere. Table 3 shows the time distribution of preset classroom regulation. It can be seen that, during preset classroom regulation, the following measures of preset classroom regulation frequently appeared in the first 20min: preset classroom teaching environment (26), raising questions about teaching contents (13), emphasis on key teaching contents (28), and transformation of teaching activities (7). Overall, preset classroom regulation is the main mode adopted by teachers to regulate the classroom. In the first half of the first class, the teachers often try to attract the students' attention through preset classroom regulation.

Table 3. Time distribution of preset classroom regulation

	[0,20]	**[20,40]**	**[40,60]**	**[60,80]**	**Total number**
Preset classroom teaching environment	26	13	13	12	64
Raising questions about teaching contents	13	17	19	8	68
Emphasis on key teaching contents	28	14	17	4	72
Transformation of teaching activities	7	8	8	7	76
Total number	74	52	57	31	280

Table 4 shows the time distribution of corrective classroom regulation. It can be seen that corrective classroom regulation is another main mode adopted by teachers to regulate the classroom. But vocal regulation (error correction, making evaluation, and explaining rules of teaching activities) and non-vocal regulation (language hints, walking and pausing, and gestures) were utilized differently. In general, vocal regulation was not so frequently used as non-vocal regulation. Language hints were mostly used during the teaching of new knowledge, aiming to inspire the students during brainstorming.

Table 4. Time distribution of corrective classroom regulation

		[0,20]	[20,40]	[40,60]	[60,80]
Vocal regulation	Error correction	3	4	5	5
	Making evaluation	6	2	3	2
	Explaining rules of teaching activities	2	8	9	8
Non-vocal regulation	Language hints	3	14	13	3
	Walking and pausing	8	8	16	9
	Gestures	4	5	8	6
Total number of vocal regulation		11	14	17	15
Total number of non-vocal regulation		15	27	35	18
Total number of corrective classroom regulation		26	41	38	33

Table 5 shows the time distribution of mandatory classroom regulation. The few number of mandatory classroom regulation indicates the good order of the classroom, i.e., the students' subjectivity is establish in hybrid learning.

Table 5. Time distribution of mandatory classroom regulation

	[0,20]	[20,40]	[40,60]	[60,80]
Named warning	1	3	5	2
Direct order	3	5	1	5
Criticism and punishment	1	2	6	3
Total number	5	10	12	10

Figure 5 presents classroom regulation effect and student experience. Note that -1 and 1 mean the students are strongly dissatisfied and satisfied with the effect of classroom regulation respectively. It can be seen that the students were inclined to believe that the hybrid learning resources are systematic, the knowledge depth is suitable, and the search for ideal knowledge consents is easy. In addition, the students are efficient in learning, and generally satisfied with the classroom regulation effect. This means the teachers have done a good job in implementing systematic and professional classroom regulation.

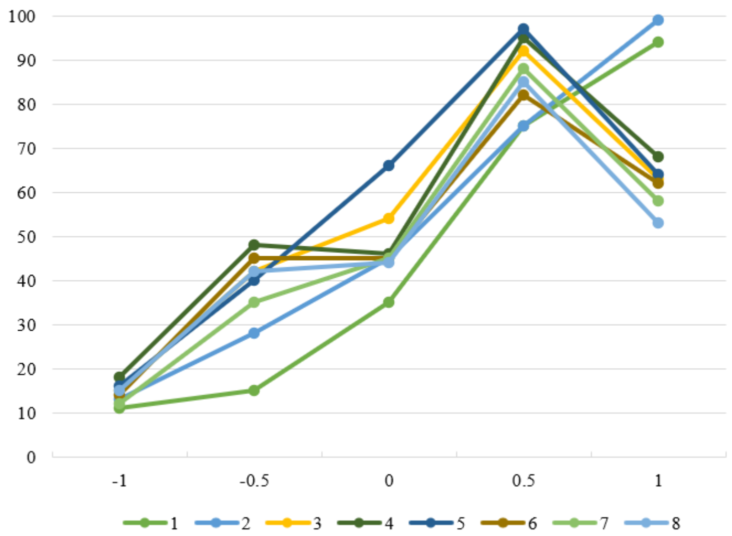

Fig. 5. Classroom regulation effect and student experience

6 Conclusions

This paper investigates the mode and effect evaluation of classroom regulation under hybrid teaching mode in colleges. Firstly, the authors preprocessed and extracted features from the data on classroom regulation indices, and explained the training process and steps of the proposed BPNN. Next, a state evaluation model was established for classroom regulation based on FCE, and the construction procedure was detailed for the multi-level FCE model. After that, the authors constructed an index system for the effect evaluation of classroom regulation under hybrid teaching mode in colleges, and classified the evaluation process of the classroom regulation effect. Through experiments, the descriptive statistics were obtained for the classroom regulation indices, and the highest and lowest factors of the three dimensions were identified, exposing the scientific direction of classroom regulation. In addition, the frequency of classroom regulation behaviors in each period of class was discussed, revealing that teachers choose different classroom regulation methods in different periods of the two classes. Furthermore, the time distribution of the three kinds of classroom regulation modes was displayed and fully analyzed. Finally, the classroom regulation effect and student experience were manifested. The results confirm that the teachers have done a good job in implementing systematic and professional classroom regulation.

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