Evaluation of the Teaching Effect in the Context of Collective Lesson Preparation

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Abstract—Now in the field of education, the pedagogy of learning from the experience of expert teachers which is participated by multiple parties and emphasizes on practicality has received the attention of field scholars, and they also began to attach importance to the cooperative features and scenarios of the Collective Lesson Preparation (CLP) of teachers and the effect of teaching reflection after practice. In order to realize sustainable and effective development of the CLP methodology, it's necessary to accurately evaluate the effect of teaching reflection of college teachers based on CLP, therefore, this paper aims to probe deep into this research topic. At first, this paper analyzed the features of CLP in actual cases, attained the connotations corresponding to these features, and gave a diagram showing the instruction and supervision mechanism of CLP. Then, referring to existing literatures and theoretical frameworks, this paper designed an Evaluation Index System (EIS) for the teaching reflection effect evaluation of college teachers based on CLP, and introduced a Back Propagation Neural Network (BPNN) into the prediction of teaching reflection effect evaluation of college teachers; after that, this paper employed Particle Swarm Optimization (PSO) to optimize the initial weight and threshold of the network, so as to improve the performance of the prediction model; at last, experimental results proved the effectiveness of the proposed model.

Keywords—Collective Lesson Preparation (CLP), college teacher, teaching reflection, effect evaluation, Back Propagation Neural Network (BPNN), Particle Swarm Optimization (PSO)

1 Introduction

The educational reform is advancing continuously in major countries and has become an irreversible trend globally, however, the effect of this reform is not ideal and the success rate is unsatisfactory, and the reason behind it is that the reform fails to exert an influence on teachers [1-6]. Since the success rate of the experience learning of teachers has a great impact on educational reform [7-11], in national policy and teaching reform practice, the Collective Lesson Preparation (CLP) methodology has become a main approach of the experience learning of college teachers [12-18]. The meaning of CLP is that for college teachers, in this era of internet and information, lesson preparation is no longer a cognition process of theoretical teaching knowledge system, it has undergone many changes, and now the pedagogy of learning from the experience of expert teachers which is participated by multiple parties and emphasizes on practicality has received the attention of field scholars, and they also began to attach importance to the cooperative features and scenarios of CLP and the effect of teaching reflection after practice.

Afterwards, as the internet and information technologies have been extensively applied in the education field, online-CLP has gradually turned into an important way to promote the professional development of teachers, and it has effectively facilitated knowledge creation, sharing, and utilization. Regarding CLP, field scholars conducted relevant studies, for example, Chen et al. [19] adopted the document research method and constructed an online-CLP knowledge transformation model based on the SECI model; then they used real cases to analyze the cyclic transformation process of teacher knowledge between individuals and organizations. To solve some common problems in electronic experimental teaching, Ren et al. [20] proposed a CLP model for electronic experimental teaching which involves a series of steps and forms such as clarifying goals, developing individuality, sharing resources, mutual authentication, evaluation, and reflection, etc. In China, with the help of modern information technologies, the pace of new curriculum reform is accelerating, for Chinese teachers, CLP via internet, namely the online-CLP, has become a new trend and platform for teachers to create, share, and use the knowledge. Jiao et al. [21] proposed a mechanism of providing dialogue space and knowledge sharing for CLP communities based on knowledge management theories and effective knowledge management. Kang [22] discussed the characteristics of excellent basic science teachers' reflection on science teaching, and analyzed the "productive reflections" of 33 excellent basic science teachers.

Current studies on CLP are mostly theoretical analysis in aspects such as concepts and orientations. Then, as new perspectives and spaces of CLP have been developed from time to time, the teaching administration departments began to intervene and affect CLP; in order to realize sustainable and effective development of the CLP methodology, it's necessary to accurately evaluate the effect of teaching reflection of college teachers based on CLP, therefore, this paper aims to probe deep into this research topic, and the content of this paper contains these chapters: Chapter 2 analyzed the features of CLP in actual cases, attained the connotations corresponding to these features, and gave a diagram showing the instruction and supervision mechanism of CLP. In Chapter 3, referring to existing literatures and theoretical frameworks, this paper designed an EIS for the teaching reflection effect evaluation of college teachers based on CLP, introduced a BPNN into the prediction of teaching reflection effect evaluation, and used PSO to optimize the initial weight and threshold of the network to improve the performance of the prediction model. Chapter 4 employed experimental results to prove the effectiveness of the proposed model.

2 CLP features of college teachers

For college teachers, the function of CLP in teaching lies in that the instructions given by expert teachers and the group discussion of teacher participators can help individual teachers better grasp the curriculum standards and the structure of teaching materials, and their ability of re-organizing the teaching content of each part in the entire teaching system could be enhanced. At the same time, the problems of some teachers, such as the doubts they encounter when preparing lessons by themselves, and the worries they have when dealing with teacher-student relationships, could be solved as well; moreover, CLP could also reduce the pressure on teachers in designing the specific teaching process, and as a result, the actual teaching effect of the courses could be improved. Each teacher has his/her own unique teaching experience and teaching style. Teachers who participate in CLP can increase their teaching experience through the sharing of teaching resources and methods, learn from each other, and make progress together; meanwhile, CLP also strengthens the communication among teachers within teaching research groups of each discipline, and promotes the sustainable development of the disciplines.

To have a good understanding of CLP, it's necessary to analyze the features of teachers in real circumstances, thereby attaining the deeper level connotations corresponding to these CLP features. This paper analyzed the CLP features of college teachers from three aspects: CLP content, CLP operation, and CLP objective.

During CLP, new joiner teachers need to pay attention to learning the teaching experience from expert teachers, and take the teaching experience they learnt as an important way to improve their own teaching quality. There're two learning directions for these new joiner teachers: the experience of lesson preparation, and the experience of classroom teaching. The learning of teaching experience focuses on the exchanges and communications between teachers during the actual teaching activities, so as to realize the sharing of teaching experience. However, the time of CLP is relatively concentrated, which has limited the ways of teaching experience sharing. In addition, teaching experience is generally based on certain disciplines or courses, so it's hard to meet the personal requirements of teachers, resulting in that the teaching experience they learnt during CLP can hardly be put into real use. These problems with CLP not only limit the development of teaching experience learning of new joiner teachers, but also dampen their enthusiasm to participate in CLP to a certain extent.

The second issue with CLP is the operation. During CLP, there're significant interactions between participant teachers, and there're certain differences in their teaching experience and teaching style. The interactions among participant teachers are mainly between primary teachers, between substitute teachers, and between primary and substitute teachers. Especially when leaders such as discipline directors or school deans participate in CLP, the interactions among participant teachers would become passive and inactive.

Besides CLP content and operation, attentions are also required for the future development of CLP. Usually, CLP would need a long-term goal, although there are large differences in the teaching content and methods of different teaching stages, the CLP goal would remain the same within a long period of time. The achievement of this long-term goal depends on the realization of staged goals, that is, the determination of the feasible staged goals is the condition for the achievement of this long-term goal. Then, how to formulate specific staged teaching goals based on the changing teaching content and methods and the diverse and personalized teaching requirements of teachers has posed a great challenge for CLP.

Through the analysis of the three aspects of CLP, here we propose the corresponding countermeasures. First, in terms of CLP content, attentions should be paid to the learning of the teaching experience of expert teachers, and more opportunities should be offered for experience sharing. Second, in terms of CLP operation, it's recognized that the main feature of CLP is the interaction between teachers who participate in CLP, it's necessary to avoid the situation that the exchange and communication between teachers become passive and inactive under the influence of interference factors, and efforts should be made to keep the exchange and communication as natural as possible. Third, in terms of CLP objective, colleges and universities should set a reasonable long-term goal for CLP, encourage teachers to consider the variability of teaching content and methods, as well as the differences in the personalized requirements of teachers; then short-term goals with high feasibility could be set to help teachers break through their obstacles in the process of their professional development via CLP.

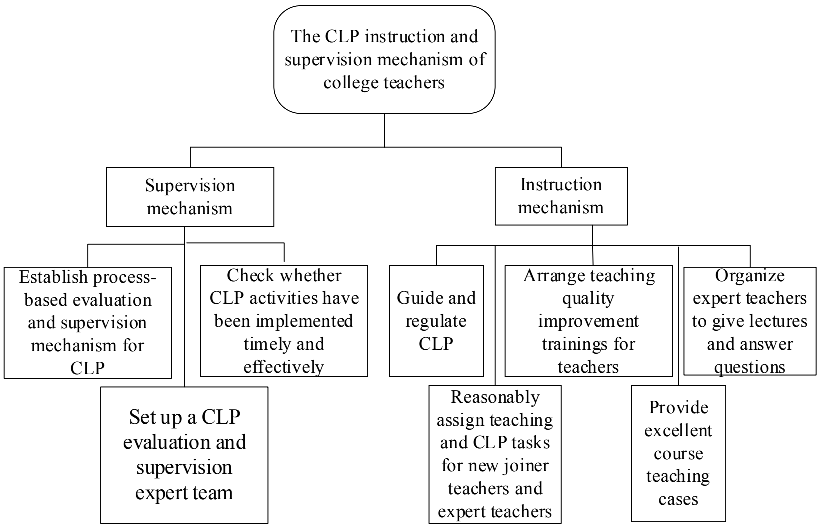

Fig. 1. The CLP instruction and supervision mechanism

The instruction and supervision mechanism of CLP is a powerful tool to prevent CLP from being a mere formality. Schools should establish process-based evaluation and supervision mechanism for CLP and implement it within a discipline or between different disciplines; they can also set up a CLP evaluation and supervision expert team which is responsible for inspecting the content, procedure, and outcome of each CLP of all disciplines or subjects in the entire school, and ensuring the CLP activities could be carried out timely and effectively. Moreover, schools should also formulate incentive measures to guide and regulate CLP, reasonably assign CLP tasks for different type teachers, arrange teaching quality improvement trainings for teachers in a timely manner, provide excellent course teaching cases for reference, organize expert teachers to give lectures and seminars and answer the questions of ordinary teachers, and make sure the participant teachers can get useful professional advices in each CLP activity.

In fact, there're contradictions in the CLP features. To further figure out the causes of these features and the factors that can interfere them, the fourth chapter will analyze and give explanation.

3 Teaching reflection effect evaluation of college teachers in the context of CLP

Referring to existing literatures and theoretical frameworks, this paper designed an EIS for teaching reflection effect evaluation of college teachers in the context of CLP, as shown in Figure 2. Based on the CIPP evaluation mode, this paper set four first-level indexes: teaching background RE_1, teaching preparation RE_2, teaching process RE_3, and teaching effect RE_4.

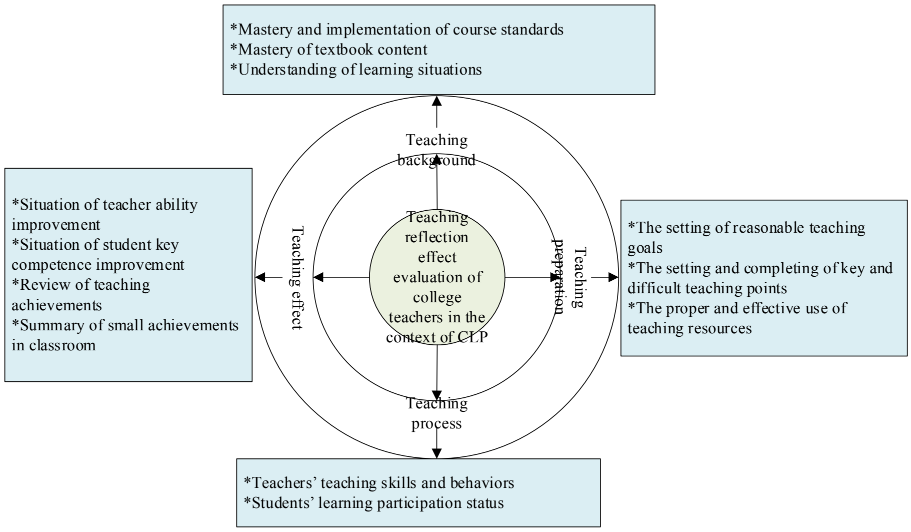

Fig. 2. EIS for teaching reflection effect evaluation of college teachers

After analyzing existing similar EISs for the teaching reflection effect evaluation of teachers, this paper adopted the influencing factor decomposition method to divide the first-level indexes mentioned above into several evaluation details, namely the second-level indexes. The first-level index, teaching background, was divided into 3 evaluation details: mastery and implementation of course standards RE_{11}, mastery of textbook content RE_{12}, and understanding of learning situations RE_{13}. The first-level index, teaching preparation, was divided into 3 evaluation details: the setting of reasonable teaching goals RE_{21}, the setting and completing of key and difficult teaching points RE_{22}, and the proper and effective use of teaching resources RE_{23}. The first-level index, teaching process, was divided into 2 evaluation details: teachers' teaching skills and behaviors RE_{31}, and students' learning participation status RE_{32}. The first-level index, teaching effect, was divided into 4 evaluation details: situation of teacher ability improvement RE_{41}, situation of student key competence improvement RE_{42}, review of teaching achievements RE_{43}, and summary of small achievements in classroom RE_{44}.

The superiority of BPNN in data processing has been recognized by world scholars. BPNN models can learn and approximate any nonlinear mapping, and have strong self-learning ability, so they are suitable for processing the index data of the EIS proposed in this paper. Thus, this paper introduced BPNN into the prediction of teaching reflection effect evaluation, and used PSO to optimize the initial weight and threshold of the network to improve the prediction performance of the model, in the hopes of providing technical support for the sustainable development of CLP and teaching reflection. Figure 3 gives the structure of BPNN.

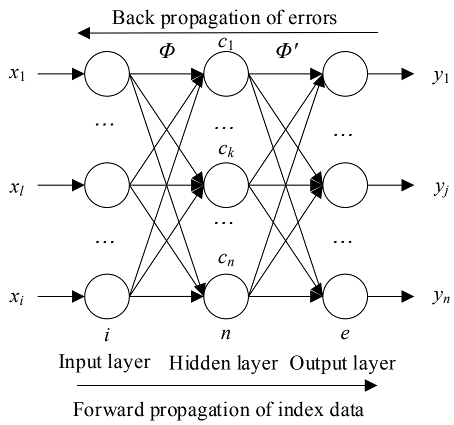

Fig. 3. The structure of BPNN

To make up for the shortcomings of BPNN in slow convergence speed and easily trapping in local optimal value, this paper adopted PSO, a method with fewer parameters and higher efficiency, to optimize it, and a PSO-improved BPNN model was then established for the teaching reflection effect evaluation problem.

Assuming: the search space of PSO has O dimensions; the size of the particle swarm is M; $U_i=(U_{i1},U_{i2},\ldots,U_{iO})$ represents the speed of the i-th particle in space O; $A_i=(A_{i1},A_{i2},\ldots,A_{iO})$ represents its position, $Q_i=(Q_{i1},Q_{i2},\ldots,Q_{iO})$ represents the extreme value of individual particle, and $Q_h=(Q_{h1},Q_{h2},\ldots,Q_{hO})$ represents the global extreme value; l represents the number of iterations; A^l_{iO} represents the position of particle i in the l-th iteration; U^l_{iO} represents the speed of particle i in the l-th iteration, and $U^l_{iO}\in[-U_{max}, U_{max}]$; U_{max} represents the maximum speed limit; Q^l_{iO} represents the extreme value of individual particle generated by the search from the start to the current iteration; Q^l_{hO}

represents the global extreme value generated by the search from the start to the current iteration; z1 and z2 represent acceleration coefficients; s1 and s2 are random numbers uniformly distributed in (0,1) interval; then the speed and position of particle Ai in the swarm are given by Formulas 1 and 2 below:

$$U_{iO}^{l+1} = U_{iO}^{l} + z_1 s_1 \left(Q_{iO}^{l} - A_{iO}^{l} \right) + z_2 s_2 \left(Q_{hO}^{l} - A_{iO}^{l} \right) \tag{1}$$

$$A_{iO}^{l+1} = A_{iO}^{l} + U_{iO}^{l+1} \tag{2}$$

The main body of the prediction model is a BPNN, the network model contains three parts: input layer, hidden layer, and output layer. The number of nodes in the input and output layers was determined based on the actual requirements of teachers' teaching reflection effect evaluation. The model uses four first-level indexes (teaching background, teaching preparation, teaching process, and teaching effect) and the corresponding 12 second-level indexes to predict teachers' teaching reflection effect in the future. Therefore, in the input layer of the BPNN, the number of neuron nodes was set to 24, and the number of neuron nodes in the output layer was set to 1.

The number of neurons in the hidden layer can directly affect the training time, generalization ability and fault tolerance of the neural network, and the training effect cannot be guaranteed if the number of neurons in the hidden layer is set unreasonably. So this research conducted experiments for multiple times according to past experience to obtain an appropriate number of hidden layer neuron nodes. Assuming: n represents the number of nodes in the hidden layer; i represents the number of nodes in the input layer; e represents the number of nodes in the output layer; λ is a constant and its value range is [1, 10], then the commonly-used empirical formula for determining the number of neurons in the hidden layer is:

$$n = \sqrt{i + e} + \lambda \tag{3}$$

This paper chose the sigmoid tangent function tansig as the transfer function of the hidden layer of the neural network, and the range of the output value of the function was [-1, 1]. Also, the Purelin function was chosen as the transfer function of the output layer of the neural network, this function is a linear function and its input and output values can be any arbitrary value:

$$\tan sig\left(m\right) = \frac{1 - d^{-a}}{1 + d^{-a}} \tag{4}$$

$$pureln\left(m\right) = m \tag{5}$$

In this paper, PSO was adopted to optimize the initial weight and threshold of the constructed BPNN. The specific steps were: first, the initial weight and threshold were regarded as the spatial position of an individual particle in PSO to determine the initial position and speed of this individual particle; then, the fitness function of PSO was set as the objective error function of the BPNN to calculate the fitness value of each individual particle in the initial swarm; after that, in order to ensure that all individual particles in the swarm always approach the global optimal value, the position and speed of individual particles were updated by Formulas 1 and 2; at last, the spatial position of the optimal individual particle output by the PSO, namely the optimal network weight and threshold values, were assigned to the constructed BPNN for training. Moreover, when optimizing the BPNN, attention needs to be paid to the mapping relationship between particles and the connection weights of the neural network.

The definition of individual particles in PSO could be completed by encoding the initial weight and threshold of the neural network using real numbers, and the number of weight and threshold of the neural network determines the number of dimensions. Assuming: the number of input layer neuron nodes of the constructed BPNN is i; the number of hidden layer neuron nodes is n, then Formula 6 gives the expression of the connection weight Φ from the input layer to the hidden layer:

$$\Phi = \begin{bmatrix} \Phi_{11} & \Phi_{12} & \cdots & \Phi_{1n} \\ \Phi_{21} & \Phi_{22} & \cdots & \Phi_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \Phi_{i1} & \Phi_{i2} & \cdots & \Phi_{in} \end{bmatrix} \tag{6}$$

The threshold vector from the input layer to the hidden layer is represented by $Y=[y_1\ y_2\ ...\ y_n]^T$, then Formula 7 gives the expression of the connection weight Φ' from the hidden layer to the output layer:

$$\Phi' = \begin{bmatrix} \Phi'_{11} & \Phi'_{12} & \cdots & \Phi'_{1e} \\ \Phi'_{21} & \Phi'_{22} & \cdots & \Phi'_{2e} \\ \cdots & \cdots & \ddots & \cdots \\ \Phi'_{n1} & \Phi_{n2} & \cdots & \Phi'_{ne} \end{bmatrix} \tag{7}$$

Assuming: M represents the number of dimensions of particles in the PSO; $Y'=[y'_1\ y'_2\ ...\ y'_n]^T$ represents the threshold vector from the hidden layer to the output layer, then Formula 8 gives the calculation formula of the number of dimensions of particles:

$$M = i \cdot n + n \cdot e + n \cdot e \tag{8}$$

Formula 9 gives the encoding form of particles in the swarm:

$$A = \left[\Phi_{11} \ \cdots \ \Phi_{in} \ \Phi'_{11} \ \cdots \ \Phi'_{ne} \ y_1 \ \cdots \ y_n \ y'_1 \ \cdots \ y'_e \right]^T \tag{9}$$

The quality of particles in the PSO was evaluated based on the size of the fitness value, which was also the basis for the iterative evolution of individual particles in the swarm, thus when optimizing the BPNN model, attention also needs to be paid to the construction of the fitness function. Since the initial weight and threshold of the BPNN are the optimal solution output by the PSO, the solution process of the algorithm can be regarded as a problem of optimizing the solution output by the PSO. In this paper, the Mean Square Error (MSE) of the BPNN was taken as the fitness function of the

PSO, assuming: N represents the number of samples in the training set; bi and b'i respectively represent the evaluation value of teacher's teaching reflection effect output by the network and the evaluation value given by experts, the specific calculation formula is:

$$G = \frac{1}{N}\sum_{1}^{N}\left(b_i - b_i^{'}\right) \tag{10}$$

4 Experimental results and analysis

After integrating and pre-processing the evaluation data of 5 experts, the judgement matrix of the evaluation indexes of college teachers' teaching reflection effect was constructed. Table 1 lists the weight and rank of each first-level and second-level evaluation index.

Table 1. Weight of evaluation indexes of teaching reflection effect of college teachers

First-level index	***RE*₁**			***RE*₂**		
Overall weight	0.1226			0.2072		
Rank	4			3		
Second-level index	RE_{11}	RE_{12}	RE_{13}	RE_{21}	RE_{22}	RE_{23}
Overall weight	0.0215	0.0415	0.0596	0.0905	0.0842	0.0325
Rank	11	9	5	6	7	10
First-level index	RE_3		RE_4			
Overall weight	0.3129		0.3573			
Rank	2		1			
Second-level index	RE_{31}	RE_{32}	RE_{41}	RE_{42}	RE_{43}	RE_{44}
Overall weight	0.1245	0.1884	0.0925	0.1262	0.1275	0.0111
Rank	4	1	5	3	2	12

After the evaluation was completed, statistical analysis software was used to analyze the evaluation data of the 5 experts and the scores of 4 samples (the teaching reflection of college teachers) of 4 grades, and finally the ANOVA and Friedman test results were sorted out. Table 2 shows the independent evaluation results given by the 5 experts to the 4 samples from 4 grades based on the constructed EIS.

Table 2. Statistics of the results of evaluation indexes of teaching reflection effect

Expert No.		**1**	**2**	**3**	**4**	**5**	**Mean**
Evaluation score	Sample 1	93.26	86.48	95.82	81.64	88.42	89.124
	Sample 2	83.08	81.68	85.93	88.76	84.09	84.708
	Sample 3	80.52	84.38	87.45	81.69	86.47	84.102
	Sample 4	86.77	83.22	91.42	86.97	85.11	86.698

According to the scores given by the 5 experts to the 4 samples of college teachers' teaching reflection, we can see that the reflection samples were highly recognized by the experts. Judging based on the mean values, the scores of Sample 2 and Sample 3 were relatively low, indicating that evaluation scores of the samples of the 4 grades were consistent with the selection levels of the samples.

Then, the evaluation scores of the samples were input into SPSS to test the Kendall coefficient of concordance and the reliability of experts. Table 3 gives the ANOVA and Friedman test results. According to the data in the table, the significance of the homogeneity test of variances was 0.095, which was greater than 0.05, indicating that the samples met the conditions for further variance analysis. The significance of variance analysis was 0.816, which was much larger than 0.05, indicating that there's no significant difference in the evaluation data of the teaching reflection effect of college teachers. The Kendall coefficient of concordance of expert scoring was 0.752, indicating that the consistency of expert scoring can reach more than 90%.

Table 3. ANOVA and Friedman test results

<table>
<tr><th></th><th>Between groups</th><th>Within groups</th><th>Total</th><th>Levene</th><th>Chi-square of Friedman test</th><th>Kendall coefficient of concordance</th></tr>
<tr><td>Sum of squares</td><td>105.719</td><td>635.428</td><td>784.125</td><td rowspan="2">2.958</td><td rowspan="2">8.5</td><td rowspan="5">0.752</td></tr>
<tr><td>df</td><td>5</td><td>13</td><td>19</td></tr>
<tr><td>Mean Square</td><td>32.628</td><td>63.147</td><td>/</td><td>Sig.</td><td>Sig.</td></tr>
<tr><td>Chi-square of Friedman test</td><td>0.475</td><td>/</td><td>/</td><td rowspan="2">0.094</td><td rowspan="2">0.036</td></tr>
<tr><td>Sig.</td><td>0.816</td><td>/</td><td>/</td></tr>
</table>

Table 4 shows the content validity index values of the evaluation indexes under the conditions of different expert numbers. This research refers to the judgment criterion of the content validity index, regardless of the number of experts, only when the content validity index value of the evaluation indexes reaches 1, the content validity of the evaluation indexes is considered to be good. After evaluating the content validity of the evaluation indexes, it's found that among the 12 evaluation indexes, the content validity index values of 8 evaluation indexes reached 1, as for the remaining 2 evaluation indexes, more than 80% of the experts had approved of them, overall speaking, the content validity of the index model was relatively ideal.

Table 4. The content validity index values under the conditions of different expert numbers

Number of experts	5	5	7	7	9	9
Number of experts who gave a score of 3 or 4	4	5	6	7	8	9
Content validity index	0.85	1	0.88	1	0.92	1
Pc	0.136	0.384	0.015	0.36	0.085	0.162
*K**	1.85	0.46	1.37	0.85	1.26	0.81
Evaluation	Average	Excellent	Excellent	Good	Average	Good

In MATLAB, the evaluation index data of college teachers' teaching reflection effect were input into the constructed BPNN for training. The obtained samples were 2552 pieces of evaluation data, which were then divided into two parts: a training set, and a test data, the sample numbers in the two sets were 2000 and 552, respectively. Figure 4 shows the MSE curves of the neural network after the training, validation, and testing were completed. As can be seen from the figure, with the increase of the number of iterations, the MSE of the neural network gradually approaches the target value and tends to be stable, indicating that the difference between predicted results of college teachers' teaching reflection effect evaluation given by the constructed model and the actual values was small, which had met the accuracy requirement.

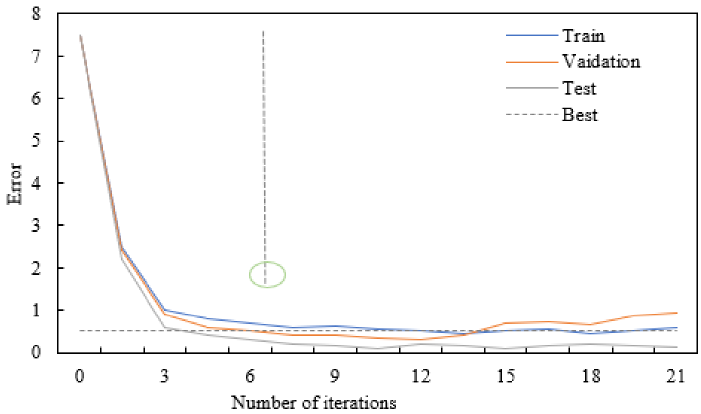

Fig. 4. MSE curves of the neural network

Figure 5 shows the curve of the fitness function of PSO. As can be seen from the figure, with the increase of the number of iterations, the fitness value of the algorithm declines obviously. When the number of iterations is greater than 90, the error of the model doesn't decrease any more, indicating that if the iteration number of the algorithm is ?, the running of the model would take a lot of time, which will have a great impact on the performance of the model. Therefore, the iteration number of the algorithm was set to 120 in this paper.

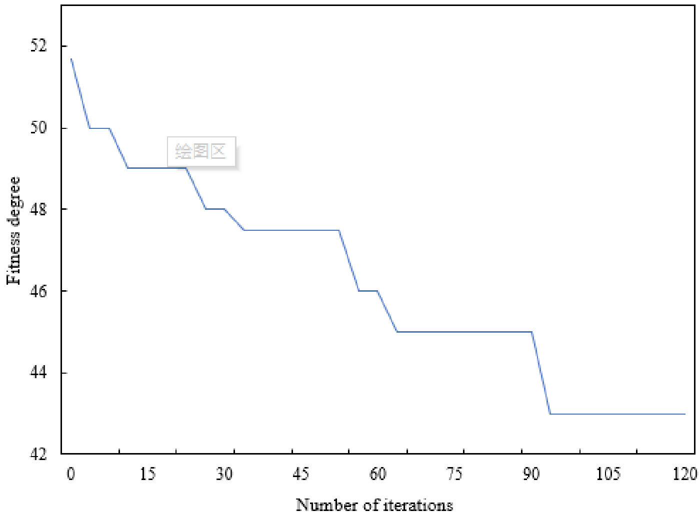

Fig. 5. The curve of the fitness function of PSO

Figure 6 shows the prediction result data of the teaching reflection effect evaluation of college teachers. In the figure, the blue and orange points correspond to the expected output values and predicted values of the evaluation results. As can be seen from the figure, the errors between the expected output values and predicted values were small, the change trends of the broken lines were not much different, which had further verified the effectiveness of the constructed model.

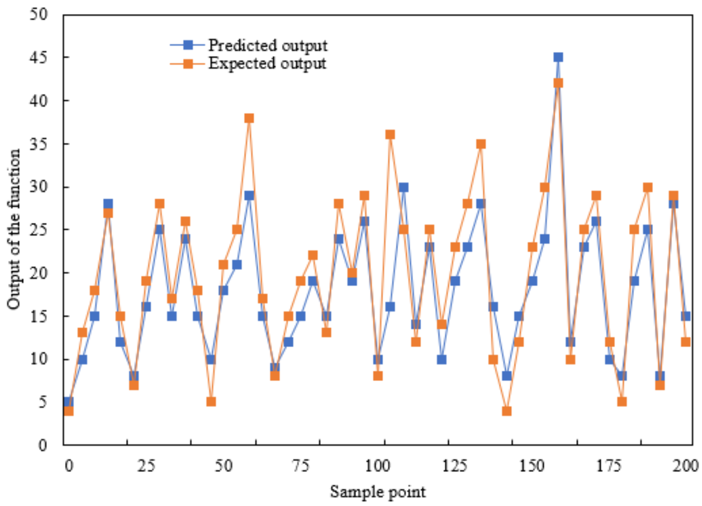

Fig. 6. Comparison of predicted results and target values of teaching reflection effect evaluation of college teachers

5 Conclusion

This paper researched the teaching reflection effect evaluation of college teachers in the context of CLP. At first, CLP features were analyzed and the corresponding connotations were obtained, and a diagram of the instruction and supervision mechanism of CLP was given. Then, based on existing literatures and theoretical frameworks, this paper designed an EIS for assessing the teaching reflection effect of college teachers, an BPNN was introduced into the prediction of teaching reflection effect evaluation, and the initial weight and threshold of the BPNN were optimized by the PSO algorithm to improve the prediction performance of the constructed model. After that, the weight ranking of the first-level and second-level indexes of the EIS was given, the evaluation results of the teaching reflection indexes were subject to ANOVA and Friedman tests, and the test results demonstrated that the overall content validity of the index model was relatively ideal. At last, the MSE curves of the neural network after the training, validation, and testing were completed, as well as the curve of the fitness function of PSO were plotted, and the predicted results of the teaching reflection effect evaluation of college teachers were compared with the target values, which had verified the effectiveness of the constructed model.

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