The Synergy Mechanism of Online-Offline Mixed Teaching Based on Teacher-Student Relationship

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Abstract—The teacher-student relationship on online education platforms is quite complex. The learning habits of different-type students and the non-contact interaction on the online education platforms make it difficult for online and offline teaching to form a synergetic relationship spontaneously, thus researching the method to construct a synergetic teaching-learning relationship between teachers and students in the context of online-offline mixed teaching is of high value. However, currently few scholars have viewed the problem of synergy mechanism of online-offline mixed teaching from a macro perspective, so in order to fill in this research gap, this paper aims to study the synergy mechanism of online-offline mixed teaching by analyzing the key factors in teacher-student relationship, including the students' background information, personality characteristics, learning preferences, learning behavior habits, types and features of the teacher-student relationship, and the interaction fitness of teachers and students, etc. In the paper, the teacher-student relationship was classified by the normal distribution division method, the calculation process of the interaction fitness degree of teachers and students was given, and a model was constructed for evaluating the synergy degree of online-offline mixed teaching. The experimental results gave a statistic of each evaluation dimension of teacher-student relationship, which had verified the effectiveness of the constructed model.

Keywords—teacher-student relationship, online-offline teaching, synergetic teaching mechanism

1 Introduction

The online education platforms and online learning modes develop very rapidly in recent years, which enables teachers and students to interact more frequently and exchange the learning resources more freely, and the big data of the behaviors of teachers and students on these platforms have been accumulated at the same time [1-6]. By mining these big data, we can promote the development of smart education, and find evidence for the feasibility of implementing synergetic teaching and learning between teachers and students [7-10]. The teacher-student relationship on online education platforms is quite complex. The learning habits of different-type students and the non-contact interaction on the online education platforms make it difficult for online and offline teaching to form a synergetic relationship spontaneously [11-19]. To achieve the ultimate purpose of realizing higher learning efficiency under the influence of good teacher-student relationship, researching the method to construct a synergetic teaching-learning relationship between teachers and students in the context of online-offline mixed teaching is of high value.

Babić et al. [20] explored the influence of the satisfaction degree of students in Croatian public and private colleges and universities with the overall teaching performance of teachers and teaching assistants on their satisfaction with online teaching mode during the COVID-19 epidemic. For higher education institutions, student satisfaction is one of their primary goals. As AI has been applied in the field of education, big data analysis is now playing a more important role in higher education and its management, and using big data to analyze behaviors and using AI to assist teaching behavior interpretation have become inevitable course for the development of education. Gong et al. [21] adopted a few technical means to collect the behavior data of teachers and students in classroom teaching, and performed cross-judgment on the multi-source data, then they introduced a complete random number algorithm and a transformation regression model to regularize the classroom data, and constructed a prediction model. Zhang [22] focused on the new teacher-student relationship in the network environment and analyzed the current status of this relationship, then the paper proposed to establish an equal and interactive relationship between teachers and students in the network environment, and discussed how teachers and students can adapt to and develop this relationship. Qu [23] discussed the advantages of collaborative learning and its application in the online and offline mixed teaching of college English, aiming to find effective ways and methods to implement the collaborative teaching mode in the online and offline mixed teaching of college English.

Studies on teacher-student relationship have made great progress in these years, but most of them viewed the problem from a single perspective, few of them are empirical research from multiple angles, and it's hard to make horizontal comparisons. Moreover, in terms of the synergy mechanism of online-offline mixed teaching, few studies viewed it from a macro perspective, so in order to fill in this research gap, this paper aims to study the synergy mechanism of online-offline mixed teaching by analyzing the key factors in teacher-student relationship. The second chapter analyzed the key factors in teacher-student relationship, including the students' background information, personality characteristics, learning preferences, learning behavior habits, types and features of the teacher-student relationship, and the interaction fitness of teachers and students, etc. The third chapter classified the teacher-student relationship using the normal distribution division method, and gave the calculation process of the interaction fitness degree of teachers and students. The fourth chapter employed the artificial neural network (ANN) and genetic algorithm (GA) to construct a model for evaluating the synergy degree of online-offline mixed teaching. At last, experimental results gave statistics of each evaluation dimension of the teacher-student relationship, which had verified the effectiveness of the proposed model.

2 Key factors in synergetic teacher-student relationship construction

When constructing the teacher-student relationship, it is necessary to consider how to connect teachers with different students, and find factors from the synergy mechanism of online-offline teaching. Figure 1 shows the structure of the teacher-student relationship under the synergetic teaching mechanism. Considering the different teaching environment and learning mode provided by online-offline mixed teaching, this paper attempts to investigate the synergetic teaching mechanism by effectively integrating the empirical theories of traditional offline classroom with the features of online-offline mixed teaching.

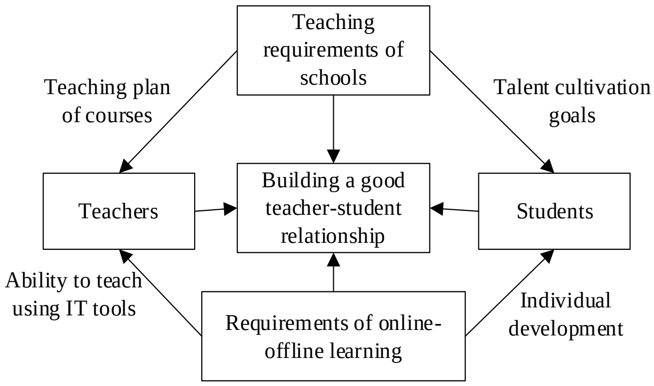

Fig. 1. The structure of teacher-student relationship under the synergy mechanism of online-offline mixed teaching

The main differences between online-offline mixed teaching and offline classroom teaching can be summarized into the following aspects: 1) In online-offline mixed teaching, students have a greater freedom to choose the teaching content; 2) There's no limitation on the learning time and space of students on online education platforms; 3) Since the geographical distance between teachers and students has been weakened by online education platforms, it is not necessary to consider the different log-in locations of students; 4) Online education platforms have provided comprehensive functional support for the communication and interaction between teachers and students.

When forming the ideal teacher-student relationship on online education platforms, external factors of teachers and students could be ignored since the communication between them is via the Internet, but the differences in the habits of students with different active learning time slots should be considered carefully, this is because it's quite difficult for teachers to form a stable and effective relationship with these students. Therefore, this paper selected the typical features and attributes of students' online and offline learning when constructing the teacher-student relationship to describe students' basic information, personality characteristics and learning preferences, learning behavior habits, types and features of teacher-student relationship, and interaction fitness degree of teachers and students in the past, etc. Figure 2 lists the key factors in teacher-student relationship construction. The specific quantification and calculation methods are explained in detail below.

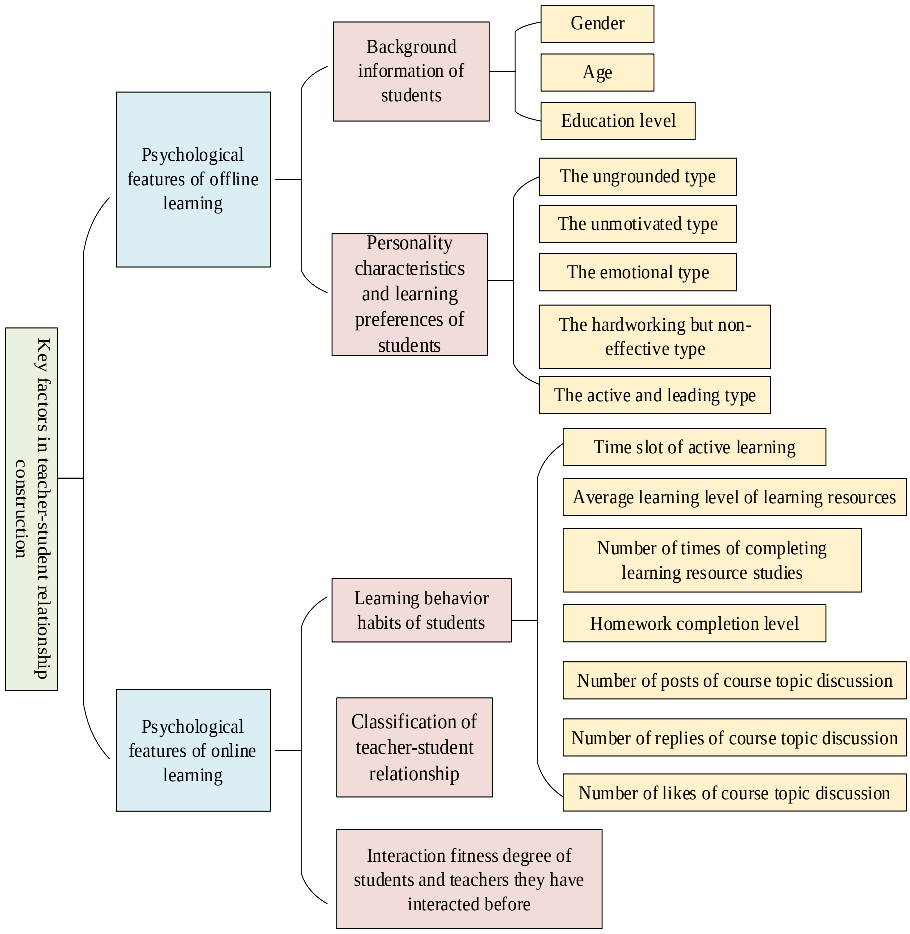

Fig. 2. Key factors in teacher-student relationship construction

The gender difference between students is an important factor affecting the construction of the student-student collaborative learning relationship, a poor student-student relationship may affect the collaboration activities of class groups and the long-term maintenance of teacher-student relationship. Assuming: *XD* represents female students; *FR* represents male students; *PH* represents unknown-gender students; then Formula 1 gives the expression of the mathematical model of student gender:

$$SQ = \begin{cases} 0, XD \\ 1, FR \\ 2, PH \end{cases} \quad (1)$$

For students in different age groups, there're certain differences in their communication ability, cognition level, expression ability, and comprehension ability, etc. Assuming: NL represents the age of students; RJ and SR respectively represent current time and the student's birth time; NLS represents age groups; then Formulas 2 and 3 give the expression of the mathematical model of student aged between 7 and 55:

$$NL = RJ - SR \quad (2)$$

$$NLS = \begin{cases} 1, NL \in (7,12) \\ 2, NL \in (13,15) \\ 3, NL \in (16,18) \\ 4, NL \in (19,30) \\ 5, NL \in (31,45) \\ 6, NL \in (46,55) \end{cases} \quad (3)$$

"Students have a greater freedom to choose the content of online-offline mixed teaching" means that different students can choose a same course, but for students with different education levels, there're differences in their learning goals and understanding of the teaching content of a same course. Assuming: EDL represents the education level; PS, JMS, SHS, BA, MA, and DOC respectively represent the education levels of primary school graduate, junior high school graduate, high school graduate, college and university graduate, master, and doctor; then Formula 4 gives the expression of the mathematical model of education level:

$$EDL = \begin{cases} 1, PS \\ 2, JMS \\ 3, SHS \\ 4, BA \\ 5, MA \\ 6, DOC \end{cases} \quad (4)$$

For different students, their learning habits and learning time slots are different as well. Assuming: am represents forenoon; pm represents afternoon; nm represents evening; mm represents late night, then Formula 5 gives the expression of the mathematical model of learning time slot:

$$TS = \begin{cases} 0, am \\ 1, pm \\ 2, nm \\ 3, mm \end{cases} \quad (5)$$

Assuming: PE(*) represents the number of clicks on learning resources; SP(*) represents the learning frequency of learning resources; d represents the set of different courses that students participate in; TW_i represents the total number of learning resources of the i-th course; TVi represents the total number of completed learning resources; then, the average learning level of learning resources (PVS), and the number of times of completing learning resource studies (AVR) are given by the following formulas:

$$PVS = \sum_{l} PE(l) * SP(l) \tag{6}$$

$$AVR = \frac{1}{d} \sum_{i}^{d} \frac{TW_i}{TV_i} \tag{7}$$

The degree of seriousness of students treating the homework assigned by teachers could be represented by the homework completion rate. Assuming: FW_i represents the amount of homework of the i-course that has been completed by students; WHW_i represents the total amount of homework, then the mathematical model of homework completion rate (PAC) is given by the formula below:

$$PAC = \frac{1}{d} \sum_{i}^{d} \frac{FW_i}{WHW_i} \tag{8}$$

3 Classification of teacher-student relationship and measurement of interaction fitness degree

In course topic discussion board of online education platforms, the questioning and answering between teachers and students and the discussions on a certain topic can reflect the interaction enthusiasm of teachers and students, which can also reflect the degree of harmony between them to a certain extent. Assuming: PIN_i represents the number of posts about the i-th course; RINi represents the number of replies; LN_i represents the number of likes; TPIN represents the level of posts in the discussion board; TRIN represents the level of replies; TLN represents the level of likes; then the specific mathematical model is:

$$TPIN = \frac{1}{d} \sum_{i}^{d} PIN_i \tag{9}$$

$$TRIN = \frac{1}{d} \sum_{i}^{d} RIN_i \tag{10}$$

$$TLN = \frac{1}{d} \sum_{i}^{d} LN_i \tag{11}$$

In the large teacher and student groups, the behavior features of the interaction between teachers and students often exhibit normal distribution, therefore, in order to better process and analyze the interaction features of teachers and students, this paper adopted the normal distribution division method to classify the teacher-student relationship, and Formulas 12-15 give the specific calculation method:

$$\lambda = \frac{1}{M}\sum_{i}^{M} a_i \tag{12}$$

$$\xi = \frac{1}{M}\sum_{i}^{M} \sqrt{\left(a_i - \lambda\right)^2} \tag{13}$$

$$a = \frac{a-\lambda}{\xi} \tag{14}$$

$$a\_SP = \begin{cases} 0, a \in \left(-\infty, -1.3\right) \\ 1, a \in \left(-1.3, -0.5\right] \\ 2, a \in \left(-0.5, 0.5\right] \\ 3, a \in \left(0.5, 1.3\right] \\ 4, a \in \left(1.3, \ \infty\right) \end{cases} \tag{15}$$

In previous learning process, if a teacher and a student behave actively, politely, and gently during interactions such as raising questions, answering questions, giving instructions, and discussing questions, then the possibility of forming a continuous and good teacher-student relationship is higher. Assuming: TEAV represents the specific text sentiment analysis value of each piece of interactive information of students and other users; Mu represents the set of positive sentiment words used during the conversation; Mm represents the set of negative sentiment words; TSEM represents the communication sentiment value between the teacher and the student; PT represents the posting time; then, the calculation process of the interaction fitness degree (SFD) between the teacher and the student can be expressed as:

$$TEAV = \frac{\sum_{i=1}^{M_t} qt_i + \sum_{i=1}^{M_m} qm_j}{M_t + M_m} \tag{16}$$

$$TSEM = \frac{1}{S}\sum_{i}^{S} \frac{TEAV_i}{RJ - PT} \tag{17}$$

$$TSEM^* = \begin{cases} \dfrac{TSEM}{max\left(TSEM\right)}, if \ \ TSEM > 0 \\ \dfrac{TSEM}{-min\left(TSEM\right)}, if \ \ TSEM < 0 \end{cases} \tag{18}$$

$$SFD = \frac{1}{TSEM^{*} + e^{-10}} \tag{19}$$

This paper used the Jaccard distance to calculate the interaction fitness distance between the teacher and the student, assuming: $M(t_i)$ represents the adjacency vector of teacher and student nodes t_i, then the specific calculation process is given below:

$$Jaccard\text{-}D = \left| \frac{M(t_i) \cap M(t_j)}{M(t_i) \cup M(t_j)} \right| \tag{20}$$

$$Jaccard\text{-}D^{*} = Jaccard\text{-}D + 10^{-5} \tag{21}$$

$$Jaccard\text{-}D^{**} = \frac{1}{Jaccard\text{-}D^{*}} \tag{22}$$

It can be seen from above formula that the Jaccard distance is the ratio of the number of teacher and student nodes with fitted interaction to the union set of the sets of all kinds of relationship between the two.

After determining the features and attributes of extracted key factors of teacher-student relationship construction, all features and attributes were integrated and built into a student feature vector matrix, denoted as FEM, and then the Euclidean distance FDIS between the vectors was calculated; the calculation processes after generating the student feature vector are:

$$FDIS = \left[\sum \left(\nabla FEM_{i,j} \right)^{2} \right]_{m \neq m} \tag{23}$$

$$FDIS' = exp\left(FDIS\right) \tag{24}$$

$$FDIS'' = min\text{-}max\left(FDIS'\right) \tag{25}$$

$$TSFR_{i,j} = \left[rand(\ ) > FDIS'' \right] \tag{26}$$

According to above analysis, this paper used the exponential function to expand the Euclidean distance FDIS, and then used the min-max normalization to expand the difference between the larger and smaller Euclidean distances, so as to fit the similarity and complementarity of the teacher-student relationship. A smaller Euclidean distance has a greater chance of building a good teacher-student relationship.

4 Evaluation of the synergy degree of online-offline mixed teaching

The synergy degree of online-offline mixed teaching can well reflect the students' basic information, personality characteristics and learning preferences, learning behavior habits, types and features of teacher-student relationship, and interaction fitness degree of teachers and students in the past. The relationships between the various factors are non-linear. In order to objectively and truthfully reflect the calculation method of the synergy degree of online-offline mixed teaching, this paper employed ANN and GA to construct a model for evaluating the synergy degree of online-offline mixed teaching.

Modeling steps of the genetic neural network are as follows:

Figure 3 gives the structure of the neural network constructed for evaluating the synergy degree of online-offline mixed teaching. Assuming: m_1 represents input layer nodes; m_2 represents hidden layer nodes; m_y represents output layer nodes; m_ω represents weight; m_y represents threshold, then the number of network structure parameters can be calculated by the following formulas:

$$m_2 = 2 \times m_1 + 1 \quad (27)$$

$$m_\omega = m_1 \times m_2 + m_2 \times m_3 \quad (28)$$

$$m_y = m_2 + m_3 \quad (29)$$

Assuming: k represents chromosome length, then Formula 30 gives the encoding formula:

$$a = a_{min} + \left(\sum_{i=1}^{k} \left(x_1 \times 2^{k-1} \right) \right) \times \frac{a_{max} - a_{min}}{2^k - 1} \quad (30)$$

The expression form of chromosome individual a is $x_k x_{k-1} \ldots x_1 x_0$, then the coding formula is:

$$a = rand(\,) \times \left(a_{max} - a_{min} \right) + a_{min} \quad (31)$$

Its expression form is given by Formula 32:

$$a = \left[a_1, a_2, \cdots, a_i \right], a = 1, 2, \cdots, i \quad (32)$$

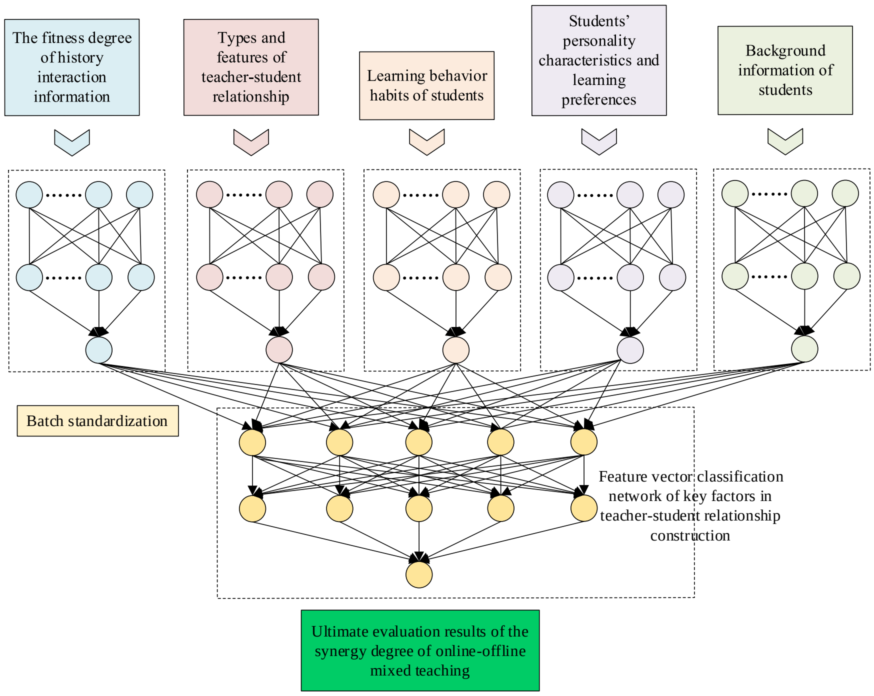

Fig. 3. The neural network structure of synergy degree evaluation of online-offline mixed teaching

5 Experimental results and analysis

Figures 4 and 5 respectively show the data changes before and after the optimization of weight and threshold. As can be seen from the figures, in order to optimize the local weight and threshold of the constructed BP neural network and alleviate the discreteness of all parameters, this paper adopted GA to optimize the constructed BP neural network and modify the weight and threshold of the network, so that the performance of the GA-optimized BP neural network could be more stable and accurate.

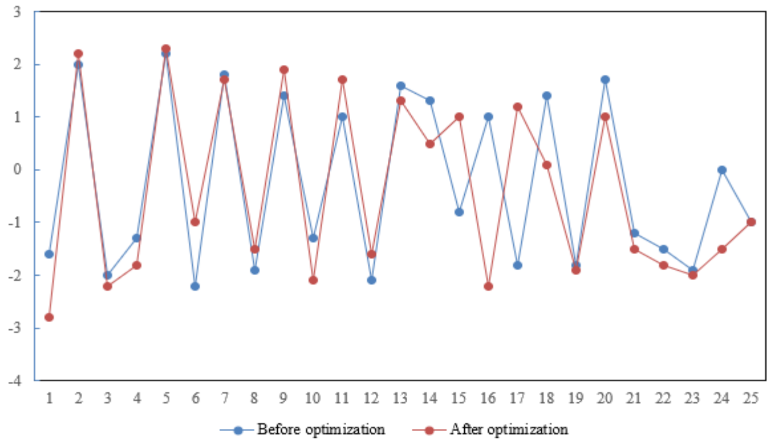

Fig. 4. Data changes before and after weight optimization

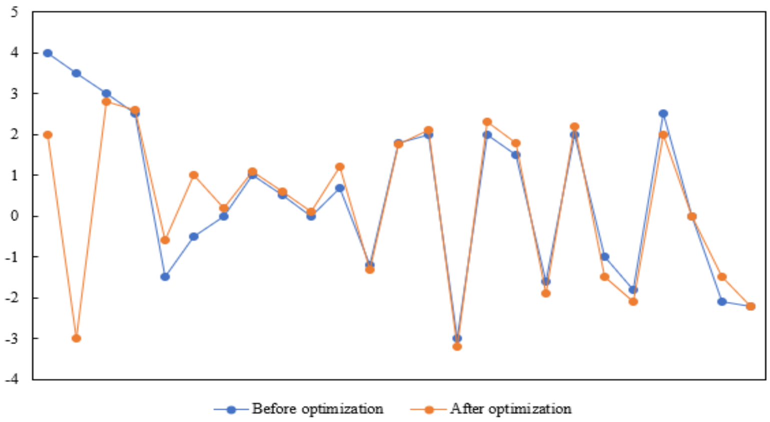

Fig. 5. Data changes before and after threshold optimization

Figure 6 shows the curve of the objective function of the GA optimization process. According to the figure, before optimized by GA, the constructed neural network needs to be trained more than 1000 times so that its training error could reach the expected value of 0.01; while after optimized by GA, the constructed neural network only needs to be trained about 100 times to reach the expected value of training error. Therefore, this paper adopted GA to optimize the constructed neural network to get the optimal initial weight and threshold, and the training efficiency of the constructed neural network had been improved effectively.

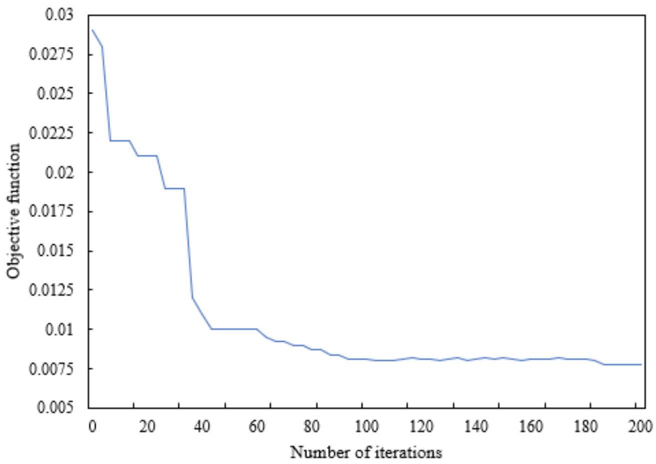

Fig. 6. Curve of the objective function of the GA optimization process

Figure 7 shows the linear regression curve of the GA-optimized BP neural network. As can be seen from the figure, for the GA-optimized BP neural network, the correlation coefficients of training samples and test samples of the synergy degree evaluation index of online-offline mixed teaching were 0.98114 and 0.945167, respectively. As for the key factors such as the students' basic information, personality characteristics and learning preferences, learning behavior habits, types and features of teacher-student relationship, and interaction fitness degree of teachers and students in the past, the GA-optimized BP neural network model achieved higher accuracy and better data fit.

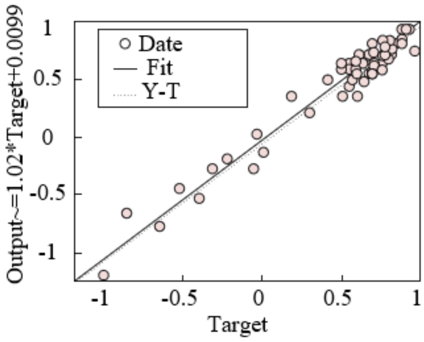

Fig. 7. Linear regression curve of the GA-optimized BP neural network

This paper measured the teacher-student relationship from four dimensions: closeness, support, satisfaction, and resistance. Table 1 shows the statistics of the four evaluation dimensions of teacher-student relationship. According to the data shown in the table, the degree of support between teachers and students was just average, the degree of closeness and the degree of satisfaction were higher, while the average score of resistance was lower, indicating that teachers had already built a balanced, harmonious, intimate, and friendly interaction mode through the communication outside the classroom.

Table 2 compares the synergy degree evaluation results of online-offline mixed teaching. The methods used include the standard method, BP neural network, particle swarm optimization (PSO), and the proposed model. Figure 8 shows the confidence levels of different models.

According to Figure 8, the GA-optimized BP neural network had achieved a high confidence level, which had verified that the optimized algorithm not only increased the stability and calculation accuracy of the constructed neural network model, but also achieved reliable model performance in evaluating the synergy degree of online-offline mixed teaching.

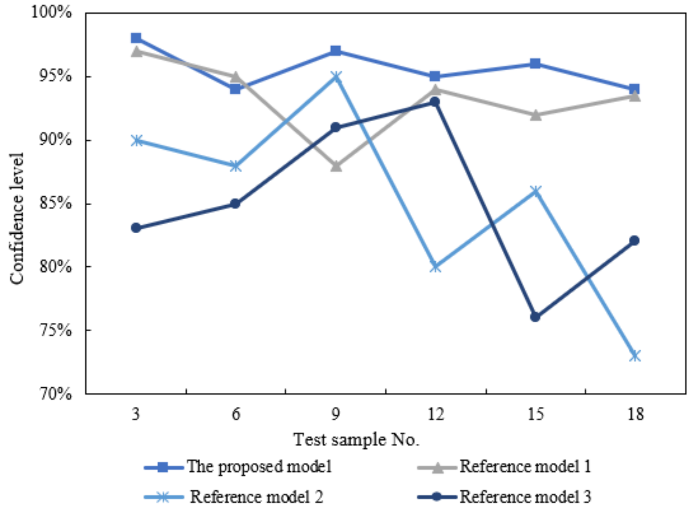

Fig. 8. Confidence levels of different models

Table 1. Statistics of evaluation dimensions of teacher-student relationship

Variable	Min	Max	Mean	Variance
Degree of closeness	6	33	22.58	6.18
Degree of support	3	24	17.39	3.24
Degree of satisfaction	8	21	25.24	4.19
Degree of resistance	5	16	12.06	5.38

Table 2. Comparison of the synergy degree evaluation results of online-offline mixed teaching

Sample No.	3	6	8	12	15	18	Evaluation result
The standard method	95.42	91.47	88.63	95.05	92.37	96.18	Stable
BP neural network	93.28	87.48	96.14	81.62	88.29	74.81	Unstable
PSO	85.17	83.27	96.48	91.83	70.64	81.69	Unstable
The proposed model	96.03	91.08	98.63	94.75	99.28	94.15	Stable

6 Conclusion

This paper studied the synergy mechanism of online-offline mixed teaching based on teacher-student relationship, and analyzed the key factors in teacher-student relationship construction, including the students' basic information, personality characteristics and learning preferences, learning behavior habits, types and features of teacher-student relationship, and interaction fitness degree of teachers and students in the past, etc. In the paper, the teacher-student relationship was classified by the normal distribution division method, the calculation process of the interaction fitness degree between a specific student and a teacher was given, and a model was constructed for evaluating the synergy degree of online-offline mixed teaching. Through experiment, this research gave the data changes before and after weight and threshold optimization, modified the weight and threshold of the constructed BP neural network, plotted the curve of the objective function of GA optimization process and the linear regression curve of the GA-optimized BP neural network, and verified that the GA-optimized BP neural network had higher accuracy and better data fit. Moreover, this paper also gave the statistics of various evaluation dimensions of the teacher-student relationship, through the data in the scale table, it's found that the teachers had already built a balanced, harmonious, intimate, and friendly interaction mode via communications with students outside the classroom. At last, this paper compared the evaluation results of the synergy degree of online-offline mixed teaching, and proved that the proposed model had a stable performance in evaluating the synergy degree of online-offline mixed teaching.

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