Analysis of Benefits of Interaction Factors of English Teaching Strategy based on Echo State Network

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Abstract
To improve the accuracy for evaluating the benefits of interaction factors of English teaching strategy, one evaluation method for the benefits of interaction factors of English teaching strategy based on Analytic Hierarchy Process and Echo State Network (AHP-ESN) has been proposed. Analytic hierarchy process has been adopted to construct evaluation index system. Indexes that have important influence on evaluation results have been screened out as echo state network input. Echo state network has been adopted to set up evaluation model for the benefits of interaction factors of English teaching strategy. Simulation results have shown that AHP-SEN not only simplifies the structure of analysis model for benefits of interaction factors of English teaching strategy, but also improves the evaluation accuracy and evaluation efficiency for the benefits of interaction factors of English teaching strategy. It is a feasible and effective evaluation method for the benefits of interaction factors of English teaching strategy.

Keywords
Analytic Hierarchy Process, Artificial Neural Network, Interaction Factor, Evaluation Model

I. Introduction

Our higher education needs to improve and promote development level continuously through reform to adapt to the demand of current new trend. In higher education, colleges and universities are main places for imparting knowledge and culture. Teaching class of university teachers is the main carrier of realizing this target. Therefore, colleges and universities have proposed higher requirements for the teaching level of teachers. It needs to take various measures to improve the benefits of interaction factors of English teaching strategy of teachers. At the moment, a lot of colleges and universities adopt the evaluation method of students scoring for teachers. This method is to divide all the courses into several categories, such as theoretical courses, internship courses and experimental courses etc, and then set some evaluation indexes for each category of courses and finally the students make anonymous scoring for teachers of the courses based on these indexes. At the end of each semester, educational administration department or school evaluation center will summarize the students' scoring to strengthen teaching management and improve the benefits of interaction factors of English teaching strategy of teachers. This method strengthens the management of school for teaching to some extent and the evaluation results present the teaching level of teachers to some extent, which make the teacher pay more attention to the feeling of students during teaching process and is good for improving the teaching level of teachers, but there are also some problems in this evaluation mechanism.

1. Teaching evaluation does not fully consider about the differences of evaluated teachers. Due to the difficulties in practical operation, the school does not set evaluation indexes based on the nature of different courses while setting the evaluation indexes. For the teachers of different subjects and at different development stages, it is not practical and impartial to adopt unified evaluation method and evaluation standards. There should be different evaluation systems for teachers of different subjects and at different development stages; there should be differences in traditional course teaching and newly opened course teaching even for teachers of the same subject and at the same development stage.
2. The subjects participated in teaching evaluation are too single, which is easy to cause one-sided results. According to traditional teaching evaluation system, the subject of teaching evaluation is student, and then the value orientation of student will directly affect the evaluation results. As the only subject for teaching evaluation, the student will cause one-sidedness of teaching evaluation to some extent. Current college students are with independent thoughts; the reputation, qualification, title, degree and cognition degree of teachers will affect the scoring results of students to some extent. At the same time, the interest of students in course study will also affect the evaluation results. They usually put more emphasis on whether the teachers are interesting, vivid and passionate in class. This orientation is very common and the results usually guide the teacher to introduce some contents irrelevant to course to cater to the evaluation standard of students, and then ignore the main contents of course. In addition, single teaching evaluation subject makes the teacher yield to students for afraid of "offending" students. They do not dare and are not willing to manage them and usually specify the examination range before examination, which causes the decrease of academic atmosphere.
3. The teaching evaluation method lacks maneuverability. Evaluation for benefits of interaction factors of English teaching strategy of teachers in colleges and universities adopts normal times and regular combination, qualitative and quantitative combination, supervision and student combination, but the evaluation for the benefits of interaction factors of English teaching strategy of teachers in colleges and universities fails to find an evaluation method, which is with strong applicability and easy for operation. In the aspect of normal times and regular combination, it lacks normal times evaluation; in the aspect of qualitative and quantitative combination, it lacks quantitative evaluation; in the aspect of supervision and student combination, it lacks supervision evaluation.

In summary, studying and setting up scientific standards and system for evaluation of benefits of interaction factors of English teaching strategy of teachers is not only the demand of school system construction and standard management, but also the direction mark of teaching behavior of teacher. This paper aims to set up a scientific and accurate evaluation system for the benefits of interaction factors of English teaching strategy of teachers and provide data support for the entry, training, boarding, promotion and development of teachers in colleges and universities, and then prepare scientific, efficient and reasonable teacher evaluation system and provide objective basis for the development of colleges and universities as well as the teachers team.

II. Mathematical Model for the Evaluation of Benefits of Interaction Factors of English Teaching Strategy

A. Form of model

Evaluation of benefits of interaction factors of English teaching strategy is to adopt theory and technology of education evaluation to make value judgment for whether the teaching process and results reach certain quality demand, which aims to promote the continuous increase of benefits of interaction factors of English teaching strategy. Teaching is a dynamic process of teaching and learning. There are a lot of factors that affect the benefits of interaction factors of English teaching strategy; in addition, due to the different influencing degrees, it causes complicated non-linear relation between input and output and it is difficult to set up a reasonable and accurate mathematical analytic formula. Set evaluation index for benefits of interaction factors of English teaching strategy as $\{x_1, x_2, \cdots, x_m\}$, and then the mathematical model for the evaluation of benefits of interaction factors of English teaching strategy is:

$$y = f(x_1, x_2, \cdots, x_m) \quad (1)$$

In the formula, f () is evaluation function. The modeling for the evaluation of benefits of interaction factors of English teaching strategy is to find the most suitable f(), which can describe the complicated non-linear relation between input and output of teaching evaluation system in a better way. As the echo state network neural network has very good non-linear learning ability, this paper adopts echo state network to make approximation for this function.

B. Set up Index System for the Evaluation of Benefits of Interaction Factors of English Teaching Strategy

The first step for setting up evaluation model for the benefits of interaction factors of English teaching strategy is to set up corresponding evaluation factor set (index system). Whether the setting of index system is scientific and reasonable or not relates to the scientificity and practicality of evaluation model directly. However, the evaluation for the benefits of interaction factors of English teaching strategy is affected by various factors, such as teaching method, teaching attitude, teaching content, class management and teaching effect. Through system analysis and expert comment and with reference to related literature and research [8-9], this paper adopts analytic hierarchy process to set up index system for the evaluation of benefits of interaction factors of English teaching strategy as shown in fig. 1. It can be learnt from fig. 1 that evaluation index domain V= (teaching method, teaching attitude, teaching content and teaching effect), each evaluation index includes several sub-evaluation indexes.

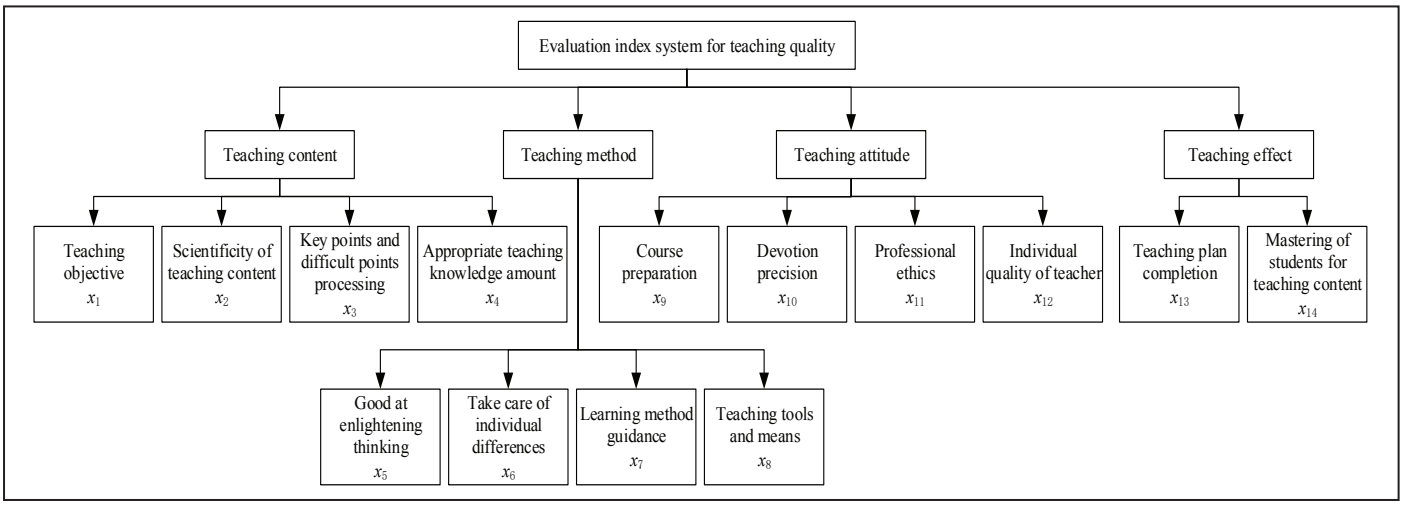

Fig. 1: Index System for the Evaluation of Benefits of Interaction Factors of English Teaching Strategy

C. AHP Screening Evaluation Index

Constructing index judgment matrix is a key step of analytic hierarchy process. To reduce the influence of subjective factors, make pairwise comparison for evaluation index for the benefits of interaction factors of English teaching strategy and construct judgment matrix A. In matrix A, element value is the relative importance degree of evaluation index for the evaluation results of benefits of interaction factors of English teaching strategy. This paper adopts teaching department and experts who are familiar with the evaluation for the benefits of interaction factors of class English teaching strategy to score together. The assignment criteria of elements in the judgment matrix are as shown in Table 1.

Table 1: Assignment Criteria of Elements in Judgment Matrix

(w_i/w_j) Assignment	Explanations
1	Two indexes are with equal importance
3	V_i index is a little more important than V_j.
5	V_i index is obviously more important than V_j.
7	V_i index is very important than V_j.
9	V_i index is extremely more important than V_j.

According to evaluation factor index matrix, firstly, it can solve W through $AW = \lambda_{max} W$, and then make normalization treatment to attain relative importance weight of corresponding index for upper level, finally make consistency test for judgment matrix. Calculate the relative importance of the same level for overall evaluation

results of benefits of interaction factors of English teaching strategy to attain comprehensive weight, and then make consistency test for judgment matrix from top level to low level. Finally, arrange evaluation indexes based on the weight of evaluation index for the benefits of interaction factors of English teaching strategy. Based on the influence weight order of each evaluation index for the final evaluation results of benefits of interaction factors of English teaching strategy, remove unimportant indexes, screen out more important evaluation index as the input of echo state network neural network, decrease the input dimension of neural network, simplify network result, speed up the learning speed of neural network and improve the evaluation accuracy and evaluation efficiency for the benefits of interaction factors of English teaching strategy.

III. Prediction for Sampling Probability Distribution of Echo State Network

In this work, it considers about adopting two different prediction methods to predict benefits of interaction factors of English teaching strategy: the first is ARIMA model for benchmark test and the second is echo state network, whose structure and training process will be described in this section. The ESN model schematic diagram of prediction for benefits of interaction factors of English teaching strategy is as shown in fig. 2.

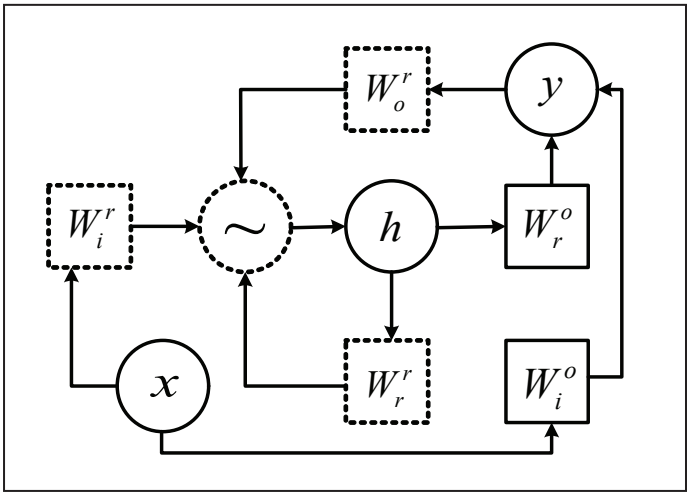

Fig. 2: ESN Model of Prediction for the Benefits of Interaction Factors of English Teaching Strategy

This model consists of three parts, including input layer, erasable memory and reading structure. The current prediction output of ESN model is calculated at two different stages. Firstly, the input vector $x[n] \in R^{Ni}$ of N_i dimension, as the input of erasable memory, its internal state $\boldsymbol{h}[n-1] \in R^{Nr}$ can be updated based on following state equation:

$$\boldsymbol{h}[n] = f_{res}(\boldsymbol{W}_i^r \boldsymbol{x}[n] + \boldsymbol{W}_r^r \boldsymbol{h}[n-1] + \boldsymbol{W}_0^r y[n-1]) \quad (2)$$

In which, $\boldsymbol{W}_i^r \in R^{N_r \times N_i}$, $\boldsymbol{W}_r^r \in R^{N_r \times N_r}$ and $\boldsymbol{W}_0^r \in R^{N_r}$ make random initialization at the start of the training process and keep unchanged. $f_{res}(\cdot)$ is a suitable non-linear function, which is usually sigmoid type function.

$y[n-1] \in R$ is the pre-scalar output of network. Here select $f_{res}(\cdot) = \tanh(\cdot)$. At the second stage, the model prediction form of ESN is:

$$y[n] = (\boldsymbol{W}_i^0)^T \boldsymbol{x}[n] + (\boldsymbol{W}_r^0)^T \boldsymbol{h}[n] \quad (3)$$

In which, $\boldsymbol{W}_i^0 \in R^{N_i}, \boldsymbol{W}_r^0 \in \in R^{N_r}$ are trainable connections. The differences between fixed and adaptive weight matrixes are as shown in fig. 2, which are expressed with solid line and dotted line respectively. In addition, to improve the overall stability, before calculating $f_{res}(\cdot)$ nonlinear transformation, it can insert a small uniform noise term to state updating equation.

In the selection of $\boldsymbol{W}_r^r$, based on ESN theory, the memory has to meet "Echo State Property" (ESP), which means that offer the state influence of input on storage, it has to disappear within limited time. For one extensively used matrix $\boldsymbol{W}_r^r$, the rule of readjusting experience is letting $\rho(\boldsymbol{W}_r^r) < 1$, in which $\rho(\cdot)$ is the spectral radius of an operator. If the ESP conditions are satisfied, ESN with suitable scale memory can make approximation for nonlinear filter at any precision level.

To confirm weight matrix, it needs to consider about Q input-output for series form as following:

$$(\boldsymbol{x}[1], d[1]), \cdots, (\boldsymbol{x}[Q], d[Q]) \quad (4)$$

In the research of this paper, the input vector is original time series X or No. i principal component β_i, the output is:

$$d[t] = x[t+m] \quad (5)$$

In which, m is the defined prediction period. At the initial stage of training, it is called as "state collection". Input is set as storage output based on formula (4). Produce an internal space series $\boldsymbol{h}[1], \cdots, \boldsymbol{h}[Q]$. Therefore, it is impossible through defining the output of ESN model. The output in formula (5) is replaced with expectation output. The state is stacked in matrix $\boldsymbol{H} \in R^{Q \times N_i + N_r}$ Expectation output is expressed as vector $\boldsymbol{d} \in R^Q$ and the form is:

$$\boldsymbol{H} = \begin{bmatrix} x^T[1], \boldsymbol{h}^T[1] \\ \vdots \\ x^T[Q], \boldsymbol{h}^T[Q] \end{bmatrix}, \ \boldsymbol{d} = \begin{bmatrix} d[1] \\ \vdots \\ d[Q] \end{bmatrix} \quad (6)$$

The initial D line in formula (6) should be deleted, because the state at this moment is in transition state. The training problem attained at this moment is a standard linear regression, which can be solved through various ways. Here adopts Least Square Regression (LSR) to handle problems. It includes regularizing least square problem in the following:

$$\boldsymbol{w}_{ls}^* = \arg\min_{\boldsymbol{w} \in R^{N_r + N_i}} \frac{1}{2} \|\boldsymbol{H}\boldsymbol{w} - \boldsymbol{d}\|_2^2 + \frac{\alpha}{2} \|\boldsymbol{w}\|_2^2 \quad (7)$$

In which, $\boldsymbol{w}_{ls} = \left[\boldsymbol{w}_i^o, \boldsymbol{w}_r^o\right]^T$, $\alpha \in R^+$ are positive scalar, which are called as regularization factors. Question (7) can be expressed as following closed form:

$$\boldsymbol{w}_{ls}^* = \left(\boldsymbol{H}^T \boldsymbol{H} + \alpha \boldsymbol{I}\right)^{-1} \boldsymbol{H}^T \boldsymbol{d} \quad (8)$$

For any $N_r + N_i > Q$, formula (8) adopts following formula for more effective calculation:

$$\boldsymbol{w}_{ls}^* = \boldsymbol{H}^T \left(\boldsymbol{H}^T \boldsymbol{H} + \alpha \boldsymbol{I}\right)^{-1} \boldsymbol{d} \quad (9)$$

IV. Estimation of sampling probability distribution

A. Algorithm Framework

EDAs algorithm is how to construct probability distribution model with higher efficiency and construct corresponding model sampling and training method. However, EDAs algorithm of standard form has two obvious shortages:

1. Difficult problem of dimension constraint, the sample data of high dimensional morphologic existence is with obvious high coupling situation;
2. Training without supervision is with un-ideal algorithm precision. For this, here adopts sampling probability model to construct new EDAs algorithm improvement version. It proposes probability distribution estimation algorithm (SPEDA) based on Gibbs.

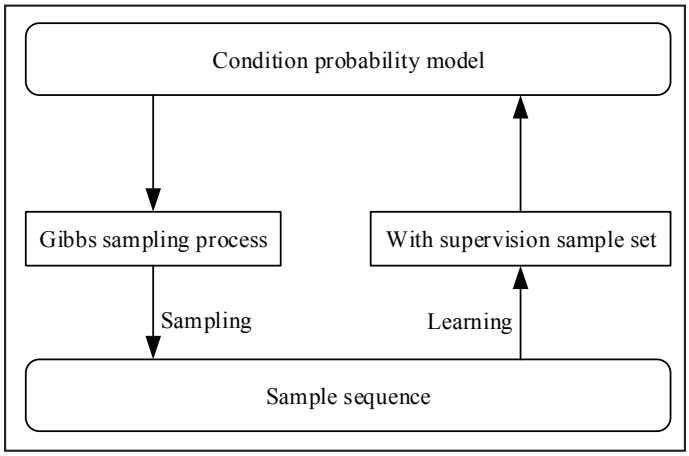

Fig. 3: Sampling Probability Model

If X is given random high dimensional vector data. The joint probability density of this vector data can be expressed as $f_X(x)$, because this probability density is with certain irregular random property, which causes that it is unable to construct direct modeling for it. The adopted solution is constructing probability $f_{x_i|x^{(i)}}\left(x_i|x^{(i)}\right)$ model. The specific process of proposed new algorithm is as shown in fig. 3.

In fig. 3 algorithm framework, adopt Gibbs sampling method, set up probability condition distribution model $f_{x_i|x^{(i)}}\left(x_i|x^{(i)}\right)$ of Markov chain feature and realize the control effect for gradual approaching joint probability distribution model $f_X(x)$.

The Gibbs sampling of algorithm is to construct new population individual through random form for each variable based on its probability condition data and distribution characteristics of current population. With adoption of this method, it can construct sample sampling sequence of Markov chain distribution feature. The steady characteristic distribution of this probability condition can approach based on probability joint distribution of this sample sampling sequence, which is also making approximation for the mean value of statistical amount $\phi(X)$ based on time mean value. Its mathematical description can be expressed as following:

$$\lim \sum_{t=1}^{T} \phi\left(X(t)\right) \Big/ T = E\left\{\phi(X)\right\} \tag{10}$$

In formula (10), mathematical formula can express the generated Markov chain sequence sample. This data sequence is with the same property as data sample attained from joint distribution model.

B. Sample Sequence Training

According to supervised sequence training method of sample, the self-learning adjustment process of execution parameter can be expressed as following:

$$Q_i = \left\{\left(x^{(i)}, x_i\right) | x \in P\right\} \tag{11}$$

In formula (11), make parameter distribution estimation for probability condition model $f_{x_i|x^{(i)}}\left(x_i|x^{(i)}\right)$. $\left(x^{(i)}, x_i\right)$ indicates that the mean value expectation of selected sample sequence $x^{(i)}$ is x_i. For easy simplification of algorithm, set the value interval of X_i as $X_i \in \{-1,1\}$, and then the estimation steps of probability condition model $f_{X_i|X^{(i)}}\left(x_i|x^{(i)}\right)$ can be expressed as:

Step 1: Construct sample classifier by combining sample sequence Q_i and corresponding classification algorithm;

Step 2: Adopt the constructed sample classifier to realize parameter distribution estimation for probability condition model $f_{X_i|X^{(i)}}\left(x_i|x^{(i)}\right)$.

Classification interface form can be defined as following:

$$g = \arg\min_{g \in G} \left\{ \sum_{Q} L\left(y, g(x)\right) \right\} \tag{12}$$

In formula (12), $Q = \{(x, y)\}$ is supervised sequence form of sample, $L(y, g(x))$ is the loss index of sample data, G is the set function candidate set. The role is to shield classification outputting un-ideal data. The constructed classification interface can be expressed as $g(x) = 0$, and then the probability condition estimation model can be expressed as:

$$\hat{P}\left(Y|X\right) \propto \exp\left[-L\left(Y, g(X)\right)\right] \tag{13}$$

In formula (13), based on above loss function and combining maximum likelihood type function of classification process, it can attain model (10) equivalent model and the form is as following:

$$g = \arg\max_{g \in G} \left\{ \prod_{(x,y) \in Q} \hat{P}\left(y|x\right) \right\} \tag{14}$$

C. Algorithm Calculation Process

Assume $(x_{opt}, fit_{opt}) = IEDA\ (eval)$ is the model expression form of EDAs algorithm. *eval* in the model is evaluation index, and then the calculation process of improved EDAs algorithm is as shown in pseudo code 2 process.

Pseudo Code 2: Estimation of Sampling Probability Distribution

1. Algorithm Initialization:

$P = \{(x(i)|i=1, \cdots, N\}, x(i) \propto Uniform\ (S), P_{opt} = \varnothing;$

2. Execute Iteration Process:

//seeking for optimization

for $ep = 1 : epoch$ do

$x^* = \arg\max_{x \in P} \{eval\ (x)\}; P_{opt} = P_{opt} \cup \{x^*\}; P = p \backslash \{x^*\};$

endfor

//learning

for $i = 1{:}D$ do

$$P_i = \left\{\left(x^{(i)}, x_i\right) \middle| x \in P_{opt}\right\} ; \quad g_i = \arg\min_{g \in G}\left\{\sum_{Q_i} L\left(y, g\left(x\right)\right)\right\} ;$$

$$P\left(X_i \middle| X^{(i)}\right) \square \exp\left(-L\left(X_i, g\left(X^{(i)}\right)\right)\right) ;$$

endfor

//sampling

$$P_{new} = sample\left(N - N_0, \left\{\hat{P}\left(X_i \middle| X^{(i)}\right)\right\}\right);$$

//updating

$$P = P_{new} \cup P_{out} ; P_{opt} = \varnothing;$$

3. Algorithm Output:

$$x_{opt} = \arg\max_{x \in P} \{eval(x)\}; fit_{opt} = eval\ (x_{opt}).$$

Construct sequence updating form for P based on data "interception" method, and then eliminate adaptive value difference individual, construct replacement for new sample realization of adaptive value difference individual based on probability sampling model, in which it can define $(N - N_0)/N$ as the elimination ratio of population individual.

D. Evaluation Steps for the Benefits of Interaction Factors of English Teaching Strategy of AHP-ESN

Step 1: Based on practical demand of expert system, frontline teacher and evaluation for the benefits of interaction factors of English teaching strategy, adopt analytic hierarchy process to set up hierarchical index system structure for the evaluation of benefits of interaction factors of English teaching strategy.

Step 2: Adopt analytic hierarchy process to calculate the comprehensive weight of teaching evaluation index and arrange based on the importance of index weight.

Step 3: Select evaluation index that has important influence on the evaluation results of benefits of interaction factors of English teaching strategy with screening method based on evaluation index weight.

Step 4: Based on the evaluation index of AHP screening, confirm the number of neurons at ESN input layer. Take the grade of evaluation for the benefits of interaction factors of English teaching strategy as model output. The number of neurons at hidden layer can be confirmed through gradual increase method, in this way, the topological structure of ESN model has been confirmed.

Step 5: Make normalization processing for index and remove the adverse effects of dimension difference of index.

Step 6: Initialize ESN parameter, select enough evaluation samples for the benefits of interaction factors of English teaching strategy, adopt ESN for its training and learning and then set up evaluation model for the benefits of interaction factors of English teaching strategy.

Step 7: Adopt the established evaluation model to evaluate the benefits of interaction factors of English teaching strategy of teachers, output evaluation results and analyze its performance.

V. Experimental Analysis

Table 2: Comparison of Evaluation Performance of Each Model

Evaluation model	Evaluation precision (%)	Correlation coefficient of practical value and model output
MLR	61.93	0.6218
AHP	70.18	0.7026
ESN	83.60	0.8465
AHP-MLR	92.48	0.9161
AHP-ESN	94.73	0.9450

To evaluate the advantages and disadvantages of AHP-ESN model, select Multiple Linear Regression (MLR), Analytic Hierarchy Process (AHP), Echo State Network Neural Network (ESN), Analytic Hierarchy Process + Multiple Linear Regression (AHP-MLR) to make comparison experiment. Adopt evaluation precision and related coefficient as the measurement standard of model and the comparison results are as shown in Table 2. The correlation changing curve of practical output and model output of MLR, AHP, ESN and AHP-ESN is as shown in figs. 4-7.

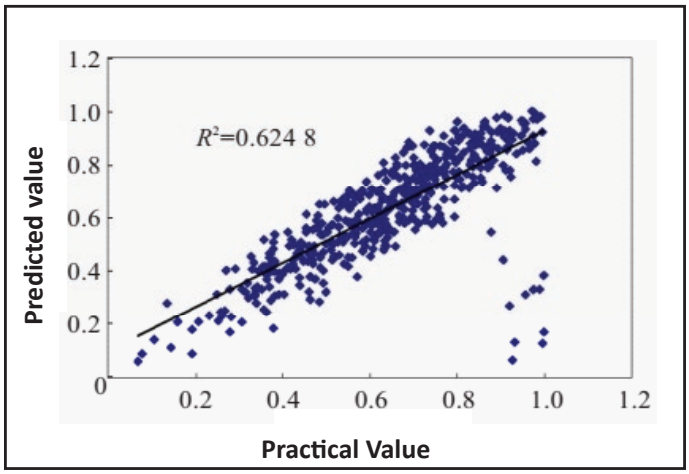

Fig. 4: Correlation Changing Curve of MLR Practical Output and Model Output

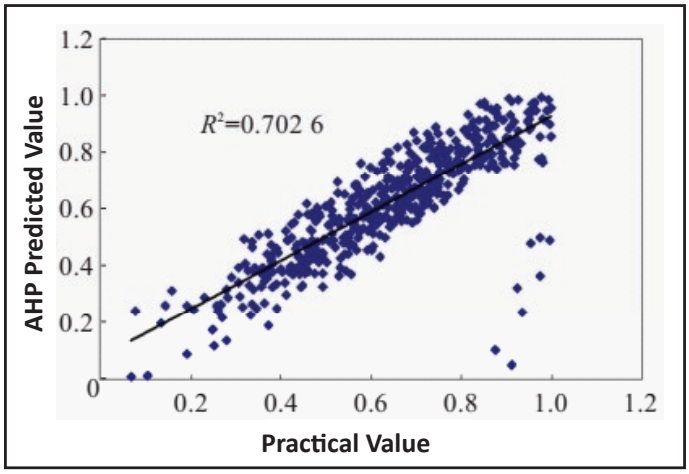

Fig. 5: Correlation Changing Curve of AHP Practical Output and Model Output

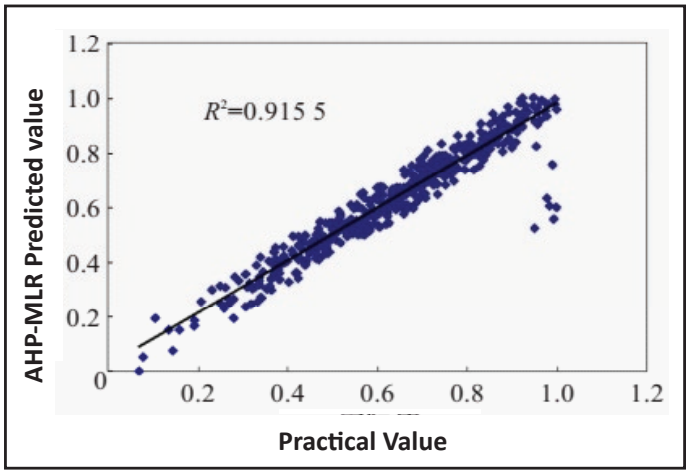

Fig. 6: Correlation Changing Curve of ESN Practical Output and Model Output

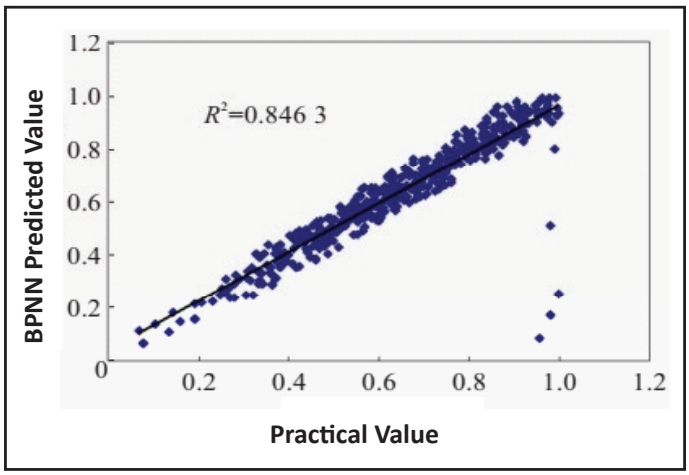

Fig. 7: Correlation Changing Curve of AHP-ESN Practical Output and Model Output

Comparison and analysis of simulation results of Table 3 and figs. 4-7 have been made. Following conclusions can be drawn:

1. The evaluation accuracy of benefits of interaction factors of combinational model AHP-MLR and AHP-ESN English teaching strategy is higher than single model, which is because combinational model adopts the advantages of single model to realize complementary advantages, provide more information reflecting the benefits of interaction factors of English teaching strategy and improve the evaluation accuracy of benefits of interaction factors of English teaching strategy effectively.
2. The evaluation results of echo state network neural network are superior to the evaluation results of MLR and AHP, which is because that the neural network is based on nonlinear modeling and is with intelligent learning ability, while MLR and AHP are based on linear modeling, which can't well reflect the nonlinear relationship between evaluation index and evaluation grade of benefits of interaction factors of English teaching strategy. Therefore, echo state network is superior to other linear models.
3. The evaluation accuracy of AHP-ESN is the highest. It indicates that adopting AHP to analyze evaluation index, screen out the most important index for evaluation results, and then adopt echo state network neural network with strong nonlinear approximation ability to evaluate benefits of interaction factors of English teaching strategy and make full use of the advantages of both. Results of these two improve the evaluation efficiency and evaluation accuracy of benefits of interaction factors of English teaching strategy, which can make effective and accurate evaluation for the benefits of interaction factors of English teaching strategy.

VI. Conclusion

For the nonlinear evaluation problem of benefits of interaction factors of English teaching strategy, one evaluation method for the benefits of interaction factors of English teaching strategy based on AHP-ESN has been proposed; performance test has been made through simulation experiment. Simulation results have shown that AHP-ESN adopts analytic hierarchy process to screen out importance index, simplify structure of neural network model and decrease model calculation time greatly; at the same time, adopt echo state network of nonlinear approximation ability to evaluate the benefits of complicated interaction factors of English teaching strategy, which can improve evaluation accuracy of benefits of interaction factors of English teaching strategy as well as the operation efficiency of evaluation system for the benefits of interaction factors of English teaching strategy. The attained evaluation results are with more scientificity and accuracy and are with better application prospect in teaching management.

VII. Acknowledgement

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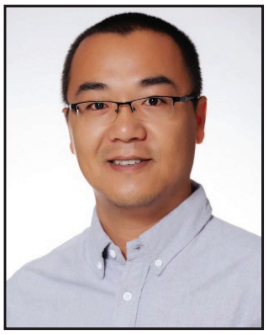

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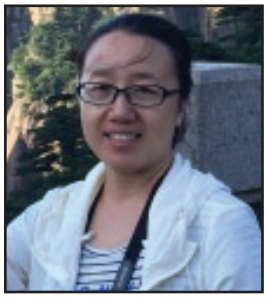

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