Establishment and analysis of quality art-evaluation model based on BP neural network

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Abstract. BP is a multi-layer feedforward neural network trained by error back propagation algorithm, which is designed to mimic the structure of biological neurons. The system could solve the problem of hidden layer connection weight learning in multi-layer neural network. Based on the influence degree of investment on art education in primary and secondary schools, four input layer neurons including the number of investment fields, the type of investment fields, the popularity rate and the utilization rate were selected to build a neural network model. The average relative error between the statistical value and the predicted value was 0.15%, which could prove that the model had a high prediction accuracy and can be applied in evaluating on primary and secondary school arts education.

1. Introduction

On August 24, 2020, "2019 National Compulsory Education Quality Monitoring -- Art Learning Quality Monitoring Results Report" was officially released, which to some extent is the concrete implementation of the first aesthetic education document "Opinions on Comprehensiveness and Improvement of School Aesthetic Education" issued by the General Office of the State Council since the founding of China.

Art education, especially elementary art education in primary and secondary schools, is very important to improve the national modernization level and enhance the comprehensive quality of students [1]. The state advocates quality education vigorously, and art education plays an important role in it, which needs to be able to better and more comprehensive adapt to the national education reform and development. Taking into account the all-round development of morality, intelligence, body and beauty, the arts education in primary and secondary schools is the foundation [2]. By the end of 2020, the investment in arts education in primary and secondary schools in China accounted for 35.5% of the national investment in arts education, and the number of arts teachers in primary and secondary schools increased by 15.36% year-on-year. The number of teachers with intermediate and higher education levels has increased as well. Therefore, the basic art education in primary and secondary schools in China has maintained a trend of rapid growth. But at the same time, there are obvious differences between urban and rural areas, between eastern and western regions, between developed and underdeveloped regions in China's basic art education. In this special case, different regions and different educational environments have different evaluation viewpoints, resulting in the differentiation and regionalization of evaluation results. Based on the phenomenon of regional imbalance of education quality, the BP neural network optimized by genetic algorithm is adopted to
establish a mathematical model of comprehensive evaluation on how to remove the non-objective results brought by differentiation and get a more real evaluation result [3]. Providing reliable support for the development of quality-oriented education and the reform of arts education system in China is one of the main concerns of the current basic arts education. In this paper, by investigating and collecting the corresponding data parameters, the BP neural network model is used to train the data samples, and the "quality evaluation model of arts education in primary and secondary schools" is obtained and the results are analyzed.

2. Data

2.1. Establishment of primary and secondary art education quality evaluation index system

The questionnaire survey is used to collect data in this evaluation, which aims to determine the evaluation index of arts education quality in primary and secondary schools. At the same time, it is also to determine the number of input layers to input the neural network in the later stage. This questionnaire survey is divided into the following steps from the design and distribution in the early stage, data recovery in the middle stage, and finally data analysis [4]:

(1) Determine the directivity of the questionnaire. The main key point of this questionnaire survey is the general public's concern about the quality of art education in primary and secondary schools. The core point of this questionnaire survey is "quality". It is necessary to clearly convey this concept to the interviewees. Due to the influence of regions, the quality of arts education in primary and secondary schools is uneven. At the same time, it is difficult to answer questions that are too specialized for ordinary people. This is not conducive to data collection, and will directly affect the accuracy of data. Therefore, the first thing to do is to collect a lot of useful information through research, filter and integrate it, and then pass it to the investigated. In addition, clear and concise language combined with pictures are used to help the interviewees to analyze.

(2) Evaluation method. The percentage system is adopted. The lower the score is, the less the respondents pay attention to this option.

(3) Target population. The target population of this questionnaire survey is mainly divided into four categories: primary and secondary school students aged 5 to 16, primary and secondary school art teacher, basic art education research scholar, ordinary primary and secondary school parents.

(4) Data processing. In the later stage of questionnaire survey, questionnaire collection and data processing were carried out. In this stage, false information will be eliminated and useful information will be retained. At the same time, the most concerned options are selected as the evaluation index of the input layer of the neural network. According to the questionnaire survey results, in "The Problems Affecting the Quality of Arts Education in Primary and Secondary Schools", it is generally believed that the most important is the capital investment in basic arts education. The strength and number of arts teachers are 75.71% and 71.23% respectively. The second is "Family's lack of basic art education for children" - the one with the smallest proportion among. See table 1.

| Questionnaire options                        | Number of respondents | Percentage |
|---------------------------------------------|-----------------------|------------|
| Capital investment of basic art education   | 623                   | 75.71%     |
| The strength and number of art teachers     | 542                   | 71.23%     |
| Art teaching method                         | 523                   | 69.42%     |
| Art education mode                          | 450                   | 56.35%     |
| National policy encouragement               | 357                   | 56.12%     |
| Family's lack of basic art education for children | 230               | 39.95%     |

Table 1. The proportion of the selected answers in the factors influencing the quality of arts education in primary and secondary schools.
2.2. Affect primary and secondary school art education quality survey
The capital investment of basic art education, the strength and quantity of art teachers are the most important factors affecting the quality of art education in primary and secondary schools. Table 2 collects the career development status of basic art education from 2009 to 2016. Data such as the proportion of basic art investment in the overall basic education investment are used to represent the development status of art teachers in primary and secondary schools.

Table 2. Development status of art teachers in primary and secondary schools (2009–2016).

| Year | Employment rate of arts graduates (%) | Average salary of art teachers in primary and secondary schools (yuan) | Transfer ratio (%) |
|------|--------------------------------------|---------------------------------------------------------------|-------------------|
| 2014 | 90.25                                | 6542                                                          | 13.58             |
| 2015 | 90.24                                | 6530                                                          | 12.0              |
| 2017 | 92.15                                | 6612                                                          | 12.68             |
| 2018 | 95.42                                | 6542                                                          | 11.27             |
| 2019 | 96.32                                | 6653                                                          | 12.54             |

As can be seen from the data in the table 2, the employment rate and average salary of art teachers in primary and secondary schools are increasing year by year. At the same time, the proportion of funds invested by the Ministry of Education in the field of arts in basic education is also increasing. This is not only related to the country's economic development, but also inseparable from the country's attention to quality education. The importance of basic art education in quality education. Relevant laws and regulations, relevant policies also prove this point.

2.3. The investment in basic art accounts for the overall investment in basic education
With the promotion of quality education by the state in recent years, people gradually realize the importance of basic art education. One of the most important is the investment of capital. The introduction of talents, the construction of art education infrastructure, the establishment of art education support institutions, all of these need the investment of funds. The economic basis determines the superstructure. Only when the funds are sufficient can the improvement of basic art education be guaranteed. Considering that investment in basic art accounts for the overall investment in basic education, it promotes the improvement of the quality of basic art education. It includes the relevant policies of the state on basic art education and the capital investment in related fields. Therefore, this paper investigates the types of capital investment in basic art education in recent years (see table 3). Formula (1) and (2) are for calculating the penetration rate and utilization rate.

\[ S_1 = \frac{\text{read}}{\text{scan}} \]  

\[ S_2 = \frac{\text{transmit}}{\text{read}} \]

Table 3. Pension rate and utilization rate of investment in basic arts education (2009–2016).

| Year | Number of types of capital investment fields | Type of capital investment field          | Penetration (%) | Utilization (%) |
|------|---------------------------------------------|------------------------------------------|----------------|----------------|
| 2014 | 3                                           | Improvement of working and teaching environment; Teachers' salary; Social Welfare of Teachers | 8.6            | 5.6            |
|      |                                             |                                          | 2.6            | 5.3            |
|      |                                             |                                          | 5.6            | 3.6            |
It can be seen from table 3 that the national investment in basic arts education is increasing, and the popularization rate and utilization rate are also increasing steadily. In 2015, the state further advocated quality-oriented education, which increased the investment in research funds and the establishment of arts education institutions, and at the same time, the popularity and utilization rate also increased accordingly. It has provided great help to the quality improvement of arts education in primary and secondary schools.

### 3. Principle and model

Error Back Propagation Training, referred to as "BP, is based on error back propagation algorithm training of the multilayer feedforward neural network. It is used to simulate the structure of biological neurons and is the most widely used neural network at present. The problem of learning the connection weight of hidden layer in multi-layer neural network is solved systematically and a complete derivation is given in mathematics. The multi-layer feedforward network which adopts this algorithm for error correction is called BP network. BP neural network has arbitrary complex mode classification ability and excellent multi-dimensional function mapping ability, which solves the exclusive OR (XOR) and some other problems that simple perceptron can't solve. Structurally, BP network has input layer, hidden layer and output layer (see figure 1). In essence, BP algorithm takes network error square as objective function and uses gradient descent method to calculate the minimum value of objective function [5].
Figure 1. BP neural network schematic diagram. ReLU activation function was used in this experiment (see figure 2)

\[ \text{ReLU}(z) = \begin{cases} 
  z & \text{if } z > 0 \\
  0 & \text{if } z \leq 0 
\end{cases} \]  

(3)

Figure 2. Image of ReLU function.

4. Experiment results and discussion
This model uses BP neural network as the modeling algorithm. The characteristics of each training sample are shown in table 3, and the annual data are taken as the training samples. The employment rate of fresh art graduates and the average salary and job transfer ratio of art teachers of middle and middle school students in table 2 are taken as the measurement of the improvement of art education quality in primary and secondary schools by the corresponding national investment in art education funds for primary and secondary schools. Before importing the training data, normalize the data in table 3 to eliminate the dimension:

\[ A' = \frac{A - \text{min}}{\text{max} - \text{min}} \]  

(4)

A is the data before normalization; A' is the normalized data; min is the minimum value in the variable; max is the maximum value in the variable.
Table 4. Types of mapped and normalized laws and regulations.

| Type of capital investment field | 1 | 2 | 3 | 4 | 5 | 6 |
|----------------------------------|---|---|---|---|---|---|
| The value of the mapping         |   |   |   |   |   |   |
| Mapping value (normalized)       | 1 | 0.23 | 0.35 | 0.1 | 0.56 | 0.23 |

Table 5. Penetration Rate and Utilization Rate of Investment in Basic Arts Education (Standardization).

| Year | Number of types of capital investment fields | Type of capital investment field | Penetration (%) | Utilization (%) |
|------|---------------------------------------------|----------------------------------|----------------|----------------|
| 2014 | 0.3                                         | 0.265                            | 0.3250         | 0.3698         |
|      |                                             | 0.2                              | 0.3551         | 0.3254         |
|      |                                             | 0.32                            | 0            | 0.0325         |
|      |                                             | 0.21                            | 0.3200         | 0.0214         |
| 2015 | 0.2                                         | 0.214                           | 0.3250         | 0.0214         |
|      |                                             | 0.32                            | 0.3205         | 0.0214         |
| 2016 | 0.21                                        | 0.214                           | 0.324          | 0.0214         |
|      |                                             | 0.324                           | 0.3044         | 0.0214         |
| 2017 | 0.23                                        | 0.325                           | 1              | 1              |
| 2018 | 0.3                                         | 0.24                            | 0.321          | 0.3254         |
|      |                                             | 0.254                           | 0.365          | 0.3214         |
|      |                                             | 0.325                           | 0.325          | 0.3251         |
| 2019 | 0.4                                         | 0.1                             | 0.2            | 0.3254         |
|      |                                             | 1                               | 0.325          | 0.2144         |
|      |                                             | 0.3                             | 0.325          | 0.3211         |

Table 4 shows the numerical mapping of the types of capital investment fields and the normalized results of Equation (4). Table 5 shows the normalized results of the impact data of art education in primary and secondary schools from 2009 to 2019.

5. Other function and parameter determination
The parameters and structure of BP neural network are shown in figure 3.
Figure 3. Structure of BP neural network.

In the network model, a batch is connected with each full connection layer, which can prevent the full connection layer from falling into over fitting and enhance the generalization ability and robustness of the model. The data from 2014 to 2017 in table 5 were used as the feature vector for model training, and the employment rate of fresh art graduates, average salary of middle school teachers and job transfer ratio in table 2 were used as the predicted TAG value. Using the data in 2018 and 2019 in table 5 as the test set, the employment rate of fresh graduates, the average salary of doctors and the job transfer rate in 2018 and 2019 are predicted. 150 rounds of testing.

Table 6. Processing and analysis of the experimental results and data of the predicted results.

| Year         | 2018   | 2019   |
|--------------|--------|--------|
| Number of types of capital investment fields | 0.325  | 0.4    |
|              | 0.24   |        |
|              | 0.254  |        |
| Type of capital investment field           | 0.325  | 0.325  |
|              | 0.24   | 0.2    |
|              | 0.254  | 0.325  |
|              |        | 0.1    |
| Penetration rate (%)                        | 1      | 0.324  |
|              | 0.321  | 0.2    |
|              | 0.365  | 0.325  |
|              |        | 1      |
| Utilization (%)                             | 1      | 0.3251 |
|              | 0.3254 | 0.3254 |
|              | 0.3214 | 0.2144 |
|              |        | 0.3211 |
| Employment rate of fresh graduates in arts (%) | 95.42  | 96.32  |
The correlation between predicted value and real value of each variable was calculated:

\[ r(X,Y) = \frac{Cov(x,y)}{\sqrt{Var[X]Var[Y]}} \]  

(5)

The results are R1 = 1, R2 = 1, R3 = 1, which means that the predicted results are positively correlated with the real values. The relative error between the real value and the predicted value was calculated:

\[ \sigma = \frac{real - predict}{predict} \times 100\% \]  

(6)

The results are as follows:

| Indicators | Penetration rate (%) | Utilization (%) | Number of types of investment fields |
|------------|----------------------|-----------------|-------------------------------------|
| Relative error(2018s) | 0.547 | 0.874 | 0.32 |
| Relative error(2019s) | 0.324 | 0.987 | 0.487 |
| Mean relative error | 0.15 | | |

The average relative error obtained in table 7 is 0.15%, which is at the excellent level, indicating that the overall prediction ability of the model is very accurate and reliable, and it can be used in practice only through training data and training indicators.

6. Conclusions

It concluded that art education in primary and secondary schools, as an important part of quality-oriented education, played an indispensable role. Art education in primary and secondary schools is an important footstone for training people to establish a correct aesthetic and outlook on life. Art education is not only a professional and technical education, but also an educational project to cultivate a complete personality. There was the characteristics of unbalanced regional development and uneven urban and rural development in the elementary arts education of primary and secondary schools in China. There was still a lot of room for progress. With the support of the state, our elementary art education in primary and secondary schools was greatly improved. We should have great confidence in this. Among the many factors affecting the quality of art education in primary and secondary schools in China, capital investment is one of the most influential factors. The role of financial input was extremely important. The model can predict the utilization rate and penetration rate of art education investment in middle and primary schools in corresponding years with a relatively small error of 0.23%. Using artificial neural network to evaluate the quality of primary and secondary art education is a nonlinear quantitative evaluation method, which can evaluate it very well. It has opened a path for the improvement of the quality of basic art education.
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