Research Article

Construction of STEAM Graded Teaching System Using Backpropagation Neural Network Model under Ability Orientation

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The use of artificial intelligence technology is one of the important focused research areas in the field of education because students need to become aware of the use of automated teaching systems within educational settings. This exploration aims to use the new teaching concept and realize a high-quality teaching effect in quality education. First, the ability-oriented Science, Technology, Engineering, Arts, and Mathematics (STEAM) education is expounded from the four aspects of ability objectives, students, projects, and teaching system construction, and the ability-oriented STEAM graded teaching system is proposed. Second, using the primary school stage as an example, combined with the thinking advanced path of cognitive psychology and the Primary School Science Curriculum Standard of Compulsory Education, a four-dimensional STEAM graded teaching system of “ability, knowledge, project, and evaluation” guided by innovative ability and involved with other abilities is constructed. Third, the shaping path and specific implementation strategies of the system are analysed. Finally, the backpropagation neural network (BPNN) model is used to evaluate the effect of STEAM graded teaching. The results show that the accuracy of students’ answers in the proposed STEAM graded teaching method is significantly higher than that in the traditional teaching method, and the evaluation error of the BPNN model is less than 1%, proving that the BPNN model has good calculation accuracy and can be used to evaluate the effect of STEAM graded teaching. This exploration provides a reference for the practice of STEAM education in China.

1. Introduction

The 21st century is the era of the information and knowledge economy. Scientific and technological innovation has increasingly become a new national development strategy. Its core is to have innovative talents with high-level abilities, such as innovative consciousness, knowledge application, and problem-solving. Science, Technology, Engineering, Arts, and Mathematics (STEAM) education, as a new educational paradigm for cultivating future comprehensive innovative talents, provides a path for the cultivation of innovative talents [1–3]. At present, China is in a period of deepening education reform. As a new education model, STEAM education is integrated into the traditional education model, which is the development trend of quality education.

The introduction of national policies has once again pushed the enthusiasm of the market for STEAM education to a climax. Many schools and educational institutions are carrying out STEAM education in full swing [4]. Hlukhaniuk et al. [5] used analytical and comprehensive methods to compare traditional and STEAM oriented methods, courses and plans, psychological pedagogy and scientific methodology literature, scientific practice conference materials on research issues, and advanced innovative teaching experience. Jamil et al. [6] used a mixed approach to understand the beliefs of preschool teachers attending STEAM teaching professional development meetings. STEAM education is an emerging method that combines STEM disciplines with art through problem-based learning to attract students and promote in-depth thinking. At present, although the domestic STEAM education shows a prosperous upward trend,
there are still some problems in its practice, such as unclear teaching objectives, incomplete curriculum system, teaching contents, and teaching products, contrary to the essence of STEAM education. It results in that the subject knowledge, teaching methods, and teaching evaluation are not established in the scientific STEAM objective system, and students’ STEAM ability cannot be accurately cultivated. Therefore, building a STEAM teaching system suitable for learners’ ability development needs has become an urgent problem to be solved, which is the focus of this exploration.

In view of the previously mentioned reasons, this exploration is to discuss the training objectives of STEAM education based on the concept of ability-oriented education and STEAM education. According to the students’ cognitive level and the law of ability development, an attempt is made to put forward the STEAM graded teaching system based on backpropagation neural network (BPNN) model under the ability orientation and further analyze and explain the shaping path and implementation strategy of the system. It is hoped that it can promote the development of STEAM teaching activities inside and outside the school, provide theoretical support for the design and development of STEAM teaching products, and cultivate students’ STEAM ability scientifically and effectively.

Key contributions of the proposed study include the following:

(1) A novel ability-oriented STEAM graded teaching system is proposed and realized for high-quality teaching

(2) Ability-oriented Science, Technology, Engineering, Arts, and Mathematics (STEAM) education is expounded from the four aspects of ability objectives, students, projects, and teaching system construction

(3) Primary school stage is effectively combined with the thinking advanced path of cognitive psychology

(4) Shaping path and specific implementation strategies of the system are analysed

(5) Backpropagation neural network (BPNN) model is adopted to evaluate the effect of STEAM graded teaching

The rest of the paper is structured as follows: Section 2 describes the proposed methodology. Section 3 is about the results generation and discussion over the results obtained. Section 4 is about the summary of the proposed study.

2. Materials and Methods

This section describes the construction of STEAM graded teaching system, backpropagation neural network (BPNN) model, and the data collection methods used in this study.

2.1. Construction of the STEAM Graded Teaching System Based on Ability Orientation

2.1.1. Basics of the STEAM Graded Teaching System under the Ability Orientation
designing STEAM teaching activities in line with students’ cognitive level and ability development law can students promote the construction of knowledge and gradually obtain STEAM ability [10, 11].

Therefore, the construction of STEAM graded teaching system suitable for students’ development is conducive to the effective implementation of STEAM education in kindergarten through twelfth grade (K12) stage in China and can help teachers accurately grasp the teaching direction of the next stage according to students’ cognitive level, formulate teaching objectives centered on students’ development, and design teaching activities to meet the real needs of students in the recent development area of students. Based on this concept, the STEAM curriculum should maintain a certain consistency and advancement in the macro. Guided by the STEAM education concept, the researchers put forward the idea of dividing the whole K12 education stage into six levels with reference to cognitive psychology and the learning advanced path of China’s basic education curriculum standards and U.S. K-12 Science Education Framework (Table 2). The STEAM graded teaching system in primary school is the focus of this exploration.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Ability objectives</th>
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| Subject knowledge | (1) Knowledge application ability: it is the ability to integrate the knowledge of science, engineering, technology, art, and mathematics to solve real problems.  
(2) Ability to analyze problems: it is the ability to comprehensively use subject knowledge to analyze problems and obtain useful conclusions.  
(3) Scientific research and exploration ability: problems are explored based on subject knowledge and scientific methods, including designing experiments, data analysis and interpretation, and drawing reasonable conclusions or forming value standards, thinking modes, and behavior through information summary.  
(4) Ability to use tools: it is the ability to select and use correct tools according to the problem, including common entity tools and science and technology. |
| Self-development | (5) Autonomous learning ability: it is the ability to achieve goals through certain self-planning, including determining learning goals, making plans, selecting learning methods, self-monitoring, and evaluation.  
(6) Cognitive ability: it is the ability of basic understanding of external things, and active exploration, thinking, and information acquisition of things through feeling, memory, observation, and imagination.  
(7) Ability to live healthily: it means recognizing and avoiding wrong health information, self-regulating health motivation and behavior, improving health skills and developing healthy living habits, including personal management, cherishing life, loving life, and healthy personality. |
| Social needs | (8) Responsibility: it refers to having a correct emotional attitude, values, and behavior towards learning, life, society, and the country. Specifically, it includes the sense of national identity, sense of social responsibility, abiding by ethics and norms in learning and practice, and performing responsibilities.  
(9) Communication and cooperation ability: students can fully communicate and discuss with other team members or students in the process of completing the project and effectively promote the solution of problems.  
(10) Problem-solving ability: it is the ability to find and analyze problems in the real project situation and formulate reasonable solutions to solve problems according to the existing conditions and knowledge.  
(11) Innovation ability: it is the ability to use existing knowledge and learning materials to produce a unique, novel, and valuable achievement and solve problems creatively in the process of discovering and analyzing problems.  
(12) Critical thinking: it is the ability to think and judge independently in project practice, analyze the obtained information and results through collected evidence and reasoning, and form their own views.  
(13) Environmental awareness: it is to learn and care for the natural environment and learn and develop the behavior of harmonious coexistence with the natural environment. |
| Cultural inheritance | (14) Humanistic accumulation: it refers to the basic ability, emotional attitude and value orientation formed by students when learning, understanding, and using relevant knowledge and skills in the humanistic field.  
(15) Human feelings: it is to respect and safeguard human dignity and value, and people care about each other, help each other, and develop together.  
(16) Aesthetic ability: the ability to discover, perceive, appreciate, and evaluate beautiful things and use artistic knowledge and skills to express creativity, so as to show the beauty in life and practice. |

(3) Cognitive Characteristics of Primary School Students. Most primary school students in China are between 7 and 12 years old. According to Piaget’s cognitive development stage theory, the cognitive level of primary school students mostly belongs to the concrete operational stage. To the senior grade of primary school, students’ cognition gradually develops from the concrete operational stage to the formal operation stage. Students in grades 1-2 (7-8 years old) are in the initial concrete operation stage, can have a simple understanding of things themselves, and begin to have a preliminary logical reasoning ability; students in grades 3-4 (9-10 years old) basically acquire the ability of logical reasoning and can solve problems related to specific things through logical methods; students in grade 5-6 (11-12 years old) get rid of the shackles of specific things and reach the advanced stage of thinking. They can complete intellectual activities including abstract and logical reasoning and use various assumptions to logically understand and solve problems based on complete hypothetical situations and existing knowledge and skills [12].

In February 2017, the Ministry of Education issued the newly revised New Subject Standard, which redivided the
Innovative ability refers to the ability of individuals to comprehensively use and master knowledge and learning materials to produce some novel and unique ideas, methods, and products with social or personal value. It is composed of three elements: innovation consciousness, innovation thinking, and innovation skills. Pupils’ innovation ability can be understood as the ability to learn new knowledge, discover new ideas, and produce new methods, the ability to discover, analyze, and creatively solve simple problems based on existing knowledge and experience, and the ability to create works of value to society or individuals. From the perspective of constructivism, the acquisition of students’ ability is the process of building their own knowledge system and applying transfer to solve practical problems. Both low-level ability and high-level ability are developed in the process of knowledge learning in various disciplines, and knowledge is the basis of ability development. Therefore, the cultivation of innovation ability should be based on discipline knowledge and skills, follow the cognitive level of students in all grades, and deeply integrate into the whole process of the construction and teaching of science, engineering, technology, art, and mathematics. It is essential to take the use of subject knowledge and skills as the method, take the creative solution of practical problems with increasing difficulty as the purpose, combine theory with practice, from shallow to deep, from simple to complex, and from low to high, constantly find problems, analyze problems, solve problems and innovate through project practice, and gradually cultivate students’ innovation ability. According to the division criteria of the previously mentioned advanced path and the thinking logic of Piaget’s stage theory of children’s cognitive development, the researchers divided the innovation ability into three levels: knowledge understanding and simple problem solving, reasoning analysis and scientific inquiry ability, and transfer and innovative practice ability. Based on the constructivism theory, a STEAM graded teaching system in primary school is established with innovation ability as the core guidance and other abilities as the participants (Figure 1).

2.2. Discussion on Graded Teaching Strategy. STEAM ability training needs to be based on subject knowledge and finally implemented into specific teaching practice. Project is a typical model of STEAM education. It focuses on the teaching of STEAM "interdisciplinary" concept and realizes the integration of STEAM education into China’s primary and secondary school curriculum system. In the process of project design, teachers should fully understand students’
cognitive level and accurately judge students’ ability level and teaching objectives. Moreover, they need to design teaching projects in line with students’ ability development based on the existing knowledge according to the changing characteristics of students’ knowledge level [18]. The project places students in real problem situations and stimulates their thirst for knowledge, challenge, and creativity. Besides, it guides them to flexibly use and transfer subject knowledge, creatively solve problems through teacher guidance and team cooperation, and finally completes the deep-seated construction of subject knowledge and ability generation, to fill the gap between students’ known and unknown abilities. The division of levels with the cultivation of innovation ability as the core goal can provide support and direction for STEAM project design, and the effective implementation of each level goal ultimately needs the corresponding teaching strategy (Figure 2).

2.2.1. Level 2: Knowledge Understanding and Simple Application Stage. Students at this stage have just entered the concrete operation stage. They have symbolic thinking, can simply think, and logically reason about some symbolic games and things but cannot understand complex abstract things. Based on the characteristics of students at this stage, project design should focus on cultivating students’ objective cognitive ability of the world and themselves through real-world physical experience and simple practical activities. It is essential to introduce students into an interesting real situation and take the problem as the main line of the whole project practice. Students complete tasks (such as space construction, color exploration, and magical notes) by playing games, small experiments, and small production, to stimulate their interest in learning and curiosity in exploring the real world, guide them to remember, understand and simply apply knowledge in the process of watching, listening, speaking, contacting, and imitating, and make preparation for them to use the acquired knowledge to solve real problems.

2.2.2. Level 3: Reasoning Analysis and Scientific Inquiry Stage. In the middle of the concrete operation stage, students’ cognitive development is gradually mature, with certain logical reasoning ability, ability to transform thinking into practice and cooperation, and communication ability. Students can analyze and deeply understand concepts according to specific situations, and summarize, reason, analyze, and solve some simple practical problems. Thereby, the project design of this stage is based on the ability obtained by students in the secondary stage, and the main goal is to understand more complex subject knowledge and apply multidisciplinary knowledge to analyze and solve practical problems. In real specific projects, students solve problems encountered in the process of project completion through team cooperation and the use of knowledge and some skills or analyze and explain a scientific phenomenon (such as observing and analyzing the survival of plants and the principle of volcanic eruption). The whole project can be divided into four parts: situation determination, problem analysis and reasoning, practical operation, and project evaluation. Continuous project practice and problem solving can deepen students’ understanding of subject knowledge and develop their problem analysis and reasoning ability, scientific exploration and practice ability, communication, and cooperation ability, to lay a foundation for the cultivation of innovation ability in the next stage.

2.2.3. Level 4: Migration and Innovation Practice Stage. Students in the transition period from concrete operation to the formal operation have improved their abstract reasoning ability, thinking transformation ability, and transfer ability, and their subject knowledge cognition and skill use are stabler. They can analyze the specific object of the problem.
from multiple angles, put forward various assumptions to reason the problem according to different situations, creatively propose multiple potential feasible solutions, and can critically think and analyze the solutions to obtain the best solutions. The project design is based on the knowledge understanding and exploration ability and practical application ability obtained in the previous two stages and aims to cultivate students’ ability to find problems from different angles, analyze problems and creatively solve problems with various methods through the application and transfer of interdisciplinary knowledge, or design items that meet the requirements of a situation theme (such as paper circuit and making fruit wine). For the problems found in the real situation, students can use assumptions to solve practical problems or design new works based on the existing subject knowledge. In the process of continuous in-depth thinking, exploration, and attempt, students can independently build knowledge, internalize, and form the ability to solve practical problems, which finally cultivate students’ critical thinking ability, problem-solving ability, and innovation ability.

Each level of project practice involves the use of primary school discipline knowledge and skills. The difficulty of knowledge structure and situational problems gradually increases from level 2 to level 4. The theme selection extends from textbook knowledge to real problems in the real world and from cognitive understanding to application exploration and to practical innovation, to gradually strengthen students’ understanding and application of discipline knowledge and gradually cultivate students’ subject literacy and STEAM ability.

2.3. Backpropagation Neural Network (BPNN). BPNN is to add a backward propagation algorithm to the structure of the feedforward network. It has not only input and output nodes, but also one or more hidden layer nodes. It is a one-way propagation multilayer forward network [19, 20]. The basic idea of this method is to use gradient search technology to minimize the mean square error between the actual output and the actual output and then perform gradient search on the output node [21]. Figure 3 shows the BPNN structure.

The input mode vector is set to

$$X^k = (x_1^k, x_2^k, \ldots, x_n^k)^T \quad (k = 1, 2, \ldots, m),$$

(1)

where $n$ represents the number of units of the input layer and $m$ represents the number of learning mode pairs.

The desired output vector of the corresponding input mode is set to

$$Y^k = (y_1^k, y_2^k, \ldots, y_q^k)^T,$$

(2)

where $q$ represents the number of units of the output layer.

The net input vector corresponding to the middle hidden layer is set as

$$S^k = (s_1^k, s_2^k, \ldots, s_p^k)^T.$$

(3)

The output vector is set to

$$B^k = (b_1^k, b_2^k, \ldots, b_p^k)^T,$$

(4)

where $p$ is the number of units of the hidden layer.

The net input vector of the output layer can be expressed as

$$L^k = (l_1^k, l_2^k, \ldots, l_q^k)^T.$$

(5)

The actual output vector can be expressed as

$$Y^k = (y_1^k, y_2^k, \ldots, y_q^k)^T.$$
If the neuron thresholds of the hidden layer and the output layer are $\alpha$ and $\beta$, the expression is as follows:

$$\alpha = \{a_0, \ldots, a_{S-1}\},$$
$$\beta = \{b_0, \ldots, b_{S-1}\}. \quad (7)$$

Figure 4 is the flowchart of BPNN.

2.4. Data Collection. One hundred students of the same grade are selected as the research object and divided into experimental group and control group. At the same learning level as usual, the control group adopts the traditional teaching method, and the experimental group adopts the STEAM graded teaching method. After three months of teaching, the students will have a 45-minute examination according to the requirements of the routine examination. Overall, 100 questionnaires are distributed and recovered. The recovery rate and effectiveness rate of the questionnaire are 100%. The design, distribution, and data collection of the questionnaire will not infringe any personal privacy and will be carried out with the consent of the participants. The questionnaire has been approved by the school leaders and relevant departments and is anonymous. The data obtained are only used for academic research. After the test, the corresponding course effect evaluation scale shall be issued to students, including student name, course content, wrong knowledge points, classroom satisfaction, content acceptance, test satisfaction, and method effectiveness. Finally, the five-point system is adopted for the four items, with 1 point for extremely dissatisfied, 2 points for dissatisfied, 3 points for basically satisfied, 4 points for very satisfied, and 5 points for extremely satisfied.
3. Results and Discussion

This section is about evaluation of the proposed methodology and critical discussion on different aspects of the proposed method and implementation details with the results obtained.

3.1. Reliability and Validity Analysis of the Questionnaire.
The reliability of the questionnaire is analyzed by SPSS 25.0. The Cronbach’s alpha obtained is 0.805, greater than 0.7, suggesting good reliability. Table 3 shows the statistical results of reliability.

<table>
<thead>
<tr>
<th>Cronbach’s alpha</th>
<th>Standardization item-based Cronbach’s alpha</th>
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</thead>
<tbody>
<tr>
<td>0.805</td>
<td>0.803</td>
</tr>
</tbody>
</table>

SPSS 25.0 is adopted to carry out Kaiser-Meyer-Olkin (KMO) and Barrett’s test on the questionnaire, and factor analysis is carried out on the questionnaire to obtain the effectiveness of the questionnaire. KMO is 0.672, greater than 0.6, so each question in the questionnaire is suitable for factor analysis and has good validity. Table 4 shows the test results of KMO and Bartlett’s test.

<table>
<thead>
<tr>
<th>KMO for sampling sufficiency</th>
<th>Measurement</th>
<th>0.672</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bartlett’s test</td>
<td>Approximate chi-square</td>
<td>145.428</td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Sig</td>
<td>0.000</td>
</tr>
</tbody>
</table>

The previously mentioned analysis shows that the designed questionnaire has good reliability and validity, and the students’ questionnaire data is reliable.

3.2. Analysis of Questionnaire Results. Figure 5 shows the answer accuracy in 100 recovered questionnaires.

Figure 5 shows that the accuracy of students’ answers using the STEAM graded teaching method proposed is basically more than 90%, while the accuracy of students’ answers after using traditional teaching is less than 90%. The answer accuracy of students using STEAM graded teaching method is significantly higher than that of traditional teaching methods. It revealed that this method can arouse students’ interest in learning, improve the classroom effect, and improve students’ academic performance.

3.3. Training Results of the BPNN Model. Figure 6 shows the BPNN evaluation results of classroom satisfaction (A), content acceptance (B), test satisfaction (C), and method effectiveness (D).

Figure 6 shows that the actual value output of the BPNN model is basically consistent with the expected value, and the difference between them is basically small, indicating that the BPNN model has good evaluation ability. The analysis of the evaluation error curve of the BPNN model reveals that the evaluation error is less than 1%. It proves that the BPNN model has good calculation accuracy and can be used to evaluate the effect of STEAM grading teaching.

4. Conclusions

The concept and teaching methods of ability-oriented education are introduced based on the concept of STEAM education. Combined with the basic curriculum standards, students’ cognitive level, and ability needs, the concept of STEAM under the ability orientation is put forward in view of the problems in the implementation of STEAM education. A STEAM graded teaching system based on BPNN under the
ability orientation is constructed by combing the characteristics of STEAM education under the ability orientation, summarizing STEAM ability, and analyzing students’ cognitive characteristics and curriculum standards. The results show that the accuracy of the STEAM graded teaching method is significantly higher than that of traditional teaching methods. This method can arouse students’ interest in learning, the classroom effect will be better, and it is more conducive to the improvement of students’ academic performance. It is hoped that, on the one hand, the construction of STEAM graded teaching system can innovate the existing STEAM teaching path and provide a reference for the practice of STEAM education in China. On the other hand, it provides the theoretical basis for educational product designers to design STEAM teaching aids that meet the STEAM education concept, students’ ability development needs, textbook teaching contents, and teaching methods.

The deficiency is that the STEAM education and teaching concept from the perspective of ability orientation is only based on the theoretical exploration of STEAM education. Its implementation details and whether it can really adapt to the current STEAM teaching inside and outside the school and promote the improvement of students’ comprehensive ability still need long-term practical verification, which is also the next research direction. Similarly, the STEAM concept in professional activities for designing and developing of research competencies in students, world-wise, have not yet been tackled and thus requires further study.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References


