Classification of critical thinking in mathematics using particle swarm optimization based neural network algorithms

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Abstract. Critical thinking in mathematics can be defined as the processes and abilities used to understand concepts, apply, synthesize and evaluate the information generated. Critical thinking in mathematics is a skill for higher order thinking. It is understood that logical thought plays a part in spiritual growth, social progress, behavioral growth, cognitive development and science progress. This study aims to classify critical thinking skills. The method used to determine the classification of critical thinking skills is to use the Neural Network algorithm. A method which has the potential to classify structured data is the neural network. In this study, a neural network algorithm model was developed. A technology that has the potential to identify structured data is the neural network. In this study, a neural network algorithm model was created. With this neural network model, it can be seen the classification of critical thinking skills. The amount of data used as data in this analysis was 150 in the form of school data and as many as 40 measures were measured in the form of math scores. On the basis of the research results, it was found that the neural network model based on Particle Swarm Optimization achieved an accuracy value of up to 93.33 percent with a 2 percent variance, tested using the k-cross-validation method.

1. Introduction
The lack of focus on developing critical thinking skills in math learning is one of Indonesian students' low capacity to solve non-routine problems. It is also possible to develop logical thinking skills through a mathematics learning cycle. Since mathematics has a framework and a clear and direct link between its principles and students who study mathematics, the ability to be sensible, logical and practical [1]. This study aims to investigate the influence of mathematical learning in high school students on quantitative critical thinking skills [2]. An significant skill that students should have is the ability to think critically, as critical thinking plays an important role for the students [3][4]. One of the key challenges facing 21st century higher education is teaching critical thinking to the students [5].

Activation functions are input mathematical operations that introduce non-linearity into neural networks and help capture non-linear input characteristics [6]. In general, the decoding function and the discriminant are selected as multilayer neural networks [7]. Neural networks may work on larger as well as small or complex data, but in both models the approach is different, the Neural Networks work somewhat like a human brain does [8]. It was proven that neural networks predictors can result in accuracy and better adjustment than other stochastic methods [9]. While this type of technique can achieve a reasonably good compression rate, the accuracy of some neural network models can be impaired [6]. The ability to think critically is one of the six value systems, namely logical values. Logic
value is the ability to think based on truth according to logic [10]. Particle Swarm Optimization is an algorithm that is one of the evolutionary algorithms that work in the process of population search or also called swarm, where each iteration is updated [11][12].

2. Methodology
The research object in this study was the average score of mathematics subjects from 150 schools in the Cirebon area, West Java, Indonesia. The purpose of this research object is to obtain data about an objective thing, namely the ability of students to think critically with good critical, fair critical, and low critical variables. Test for Thought. This formula is used as the test result [13]:

\[ P = \frac{\text{Score gained}}{\text{Maximum score}} \times 100 \]

The categories used based on the following criteria:

| Average score | Criteria    |
|---------------|-------------|
| 75% ≤ P < 100%| Good        |
| 60% ≤ P < 75% | Fair        |
| 0% ≤ P < 60%  | Low         |

The indicators tested included 40 sub-subjects of mathematics, namely algebraic values, root form operation results, logarithmic forms, multiplication of two matrices, inverse matrices, results of algebraic operations, two-variable linear equation multiplication systems, quadratic equations, quadratic function graphs, system models linear inequalities, optimum functions, linear programming, arithmetic series, geometric series, arithmetic series and geometry. Geometry and Trig values, the determinant of the \( \sin C \) value of a right triangle, a pair of fields that cross each other, the distance between two points in the form of three vertical sides, Cartesian coordinates of polar coordinates, point coordinates, point image coordinates, distance from one corner point cube, determinants in the form of bar, circle or line graphs, single data variance, group average value model, counting rules, permutations, event likelihood, probability of two events, frequency problem, combination, limit value of a function, derivative of function Fractional algebra, increasing / decreasing function intervals, tangent equations, indefinite integral algebraic functions, and derivatives, here are the data objects as shown in Figure 1.

![Figure 1. Object of Research](image)

Artificial neural networks are a model that is often used for classification. Neural network or also known as neural network. Neural networks are applied to solve long-term dependency learning problems and observed disappearing or exploding gradients with long sequences [14]. Most of the research has been done in the field of behavior recognition by taking Neural Networks, SVM and Random Woods and others. Neural Networks can be used for sports images to segment and evaluate [8].
Optimization has the benefit of being quick to introduce. In several algorithms, the use of Particle Swarm Optimization includes those for function optimization, in fuzzy control systems, and neural network preparation [15]. We can see the Particle Swarm Optimization equation:

\[
x_i^t = \{x_{i1}^t, x_{i2}^t, \ldots, x_{id}^t\}
\]

(1)

\[
v_i^t = \{v_{i1}^t, v_{i2}^t, \ldots, v_{id}^t\}
\]

(2)

\[
v_i^t = wv_i^{t-1} + c_1r_1(Pfd - x_{id}^t) + c_2r_2(Pgd - x_{id}^t), d = 1,2, \ldots, D
\]

(3)

\[
X_{id} = \{X_{id}, V_{id}, d = 1,2, \ldots, D\}
\]

(4)

If I hold a candidate position, t is repetition, x and v are dimensional, the best global particle location is pgd, r is random, c1 and c2 are constant, and inertia is w weight.

3. Related Work

In previous research on critical thinking in previous studies [2][4] The critical thinking of the alumni was defined by the role of the teacher in creating educational frameworks that allowed for a new situation. Students rate their degree of critical thinking growth as strong, but it is found that it did not manifest itself in circumstances requiring the application of the same aspects which could be considered a significant indicator of the standard of higher education [4]. The approach retrieves the ROP prediction model from the well logs successfully, and also obtains the best operating parameters through Particle Swarm Optimization algorithms. Results from the case study show our method is consistent and efficient [16].

The accuracy increased by 90.55 percent to the overall degree of accuracy based on the effects of the tests conducted on the proposed model. The method utilizing hybrid Particle Swarm Optimization -IG is a solution as an effort to increase the degree of precision in the study of food restaurant classification as knowledge supporting the decision [14]. The results of this forecast are a guide and benchmark for the government in deciding and policymaking to reduce the rates of an alphabet. The data to be anticipated are the illiteracy rate data for each province in Indonesia from the Indonesian Central Bureau of Statistics from 2011 to 2017. Artificial Neural Network Backpropagation is the instrument used for predicting [17].

The data has been carried out by data clustering techniques on the variables in critical thinking so that it can improve the classification results. Clustering techniques is a data mining technique used to analyze data to solve problems in grouping data or more precisely partitioning datasets into subsets [11]. In previous research on critical thinking in previous studies [2][4], The critical thinking of the alumni was defined by the role of the teacher in creating educational frameworks that allowed for a new situation. Students rate their degree of critical thinking growth as strong, but it is found that it did not manifest itself in circumstances requiring the application of the same aspects which could be considered a significant indicator of the standard of higher education [4].

4. Result and Discussion

Research on critical thinking classification in mathematics is obtained using a neural network algorithm based on particle swarm optimization using rapid miner 7.5. The label of this critical thinking classification includes non-critical, critical and very critical, with the specified network parameters, namely: limited signal in the threshold area between 0 to 1, the number of hidden layers used 1 and 2, Learning rate, in this system, The learning constant used is 0.01 to 0.09, the momentum value used is 0.1, and the number of training cycles is 200.
Figure 2. Particle Swarm Optimization Neural Network Algorithm Design

Figure 3. Neural Network Algorithm Design

The results obtained from the classification accuracy of the application of the Particle Swarm Optimization-based neural network algorithm are 93.33 percent. This model uses Cross validation with an nFold of 10 and the type of sample is stratified sampling. From 150 data, it was produced a critical prediction of 92.54 percent, 100 percent very critical prediction, and 0 percent less critical prediction. The results of the accuracy of this study are as shown in the figure 4.

Figure 4. Accuracy with Particle Swarm Optimization Based Neural Network

While the classification accuracy results from the application of the neural network algorithm are 91.33%. This model uses Cross validation with an nFold of 10 and the type of sample is stratified sampling. From 150 data, 91.85% critical prediction was produced, but 1 was stated as very critical, 100% very critical prediction, and 0% less critical prediction. The accuracy of this study is shown in Figure 5

Figure 5. Accuracy with Neural Network

From the results, it is found that critical thinking from students is strongly influenced by v2, v5, v18, and v36, namely in the algebra material in the discussion of Determining the value of a logarithmic
form, Determining the results of algebraic operations from variables, on geometric and trigonometric materials, namely the sub-discussion Determining coordinates Cartesian of the given polar coordinates, in the calculus material, namely the sub-discussion of Determining indefinite integrals of algebraic functions. As shown in Figure 6 below:

![Figure 6. Critical Thinking in Mathematics Using Particle Swarm Optimization](image)

In this study, testing the Neural Network Algorithm using 4 parameters including training cycles, learning rate, momentum, accuracy. This test begins with the determination of the value of training cycles, in this study the value of training cycles is determined by conducting a trial by entering the value range of 200 for training cycles, as well as 0.1 for learning rate and 0.01 for momentum. The classification accuracy results from the application of the neural network algorithm that has been tested with momentum and leaning rate 9 times, the results obtained are 93.33 percent accuracy using Particle Swarm Optimization-based neural network algorithm, while using Cros validation with nFold the results vary with average accuracy results. 90.43 percent, the findings of Particle Swarm Optimization-based Neural and Neural Networks accuracy can be seen in the table below.

**Table 2. Accuracy with NN + Particle Swarm Optimization**

| No | Training Cycle | Momentum | Learning Rate | Accuracy NN | Accuracy NN + Particle Swarm Optimization |
|----|----------------|----------|---------------|-------------|-------------------------------------------|
| 1  | 200            | 0.1      | 0.01          | 82.67%      | 93.33%                                    |
| 2  | 200            | 0.1      | 0.02          | 88.00%      | 93.33%                                    |
| 3  | 200            | 0.1      | 0.03          | 89.86%      | 93.33%                                    |
| 4  | 200            | 0.1      | 0.04          | 91.33%      | 93.33%                                    |
| 5  | 200            | 0.1      | 0.05          | 92.00%      | 93.33%                                    |
| 6  | 200            | 0.1      | 0.06          | 92.00%      | 93.33%                                    |
| 7  | 200            | 0.1      | 0.07          | 92.67%      | 93.33%                                    |
| 8  | 200            | 0.1      | 0.08          | 92.67%      | 93.33%                                    |
| 9  | 200            | 0.1      | 0.09          | 92.67%      | 93.33%                                    |

Analysis of the Critical Thinking classification in Mathematics with the optimization process model using the neural network process model with 200 training cycle parameters, 0.1 momentum, and a learning rate of 0.01 to 0.05, the accuracy value has increased by 2.35 percent, and at a learning rate of 0.05 to 0.09, it obtained a fixed accuracy value of 92.67 percent. Meanwhile, the Particle Swarm Optimization paradigm will make a major improvement, namely a rise in the degree of precision. For the highest precision, it will help the task of selecting the right example. It is 93.33 percent of the Particle Swarm Optimization -based Neural Network Algorithm method model.
5. Conclusion
In this study, the classification of critical thinking in Mathematics uses a Neural network algorithm model based on Particle Swarm Optimization with an accuracy of 93.33 percent. Compared to an implementation using only a neural network, our scheme uses a minimal number of features.

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