Correlation of self-efficacy and mathematical critical thinking skills based on student’s cognitive stage

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Abstract. Self-efficacy (SE) and critical mathematical thinking skills (MCTS) have been studied extensively. But study about the correlation of both based on student’s cognitive stages (SCS) is rarely done. This study involved 25 students from seventh grade determined by purposive sampling technique in one of the schools in Cimahi. The instrument used the Longeot test, Test of Logical Thinking (TOLT), an Essay MCTS, and a scale of SE. Data analysis performed: percentage calculation, testing of mean difference, and correlations testing at a significance level of 5%. Based on the results and discussion it was concluded that, in general, the SCS classification of seventh grade students based on the Longeot Test and TOLT scores was obtained 24% of students were in the concrete stage, 68% of students were in the transition stage, and 8% of students were in the formal stage. This means that most seventh grade students are in the transition stage. There are differences in MCTS based on SCS in a very weak category. There is no difference in SE based on SCS with enough categories. The relations of SE and MCTS based on SCS is not significant in the low category.

1. Introduction
The children's cognitive development stage can be characterized by special intelligence shown by the child according to the rules of time. This is Piaget's four cognitive development stage with distribution age [1,2,3,4,5] as follows: (a) Sensory-motor stage from birth to about 2 years old; (b) Pre-operation stage from around 2 to 7 years; (c) Concrete operation stage from around 7 to 12 years old; and (d) Formal operation stage from around 12 years old to adult. The distribution of cognitive stage age also applies to children in Indonesia and the sequence of cognitive stages can apply equally to every human being, but the age of a child entering or not to a higher stage can vary depending on the unique experience of children in their environment [6,7].

To classify the SCS requires the right test. The type of test suggested [8] is a logical reasoning test consisting of The Longeot Test and Test of Logical Thinking (TOLT). After knowing the SCS, it is expected to help educators in implementing mathematical learning in accordance with SCS, so that learning is more meaningful and can contribute greatly to the achievement of high order thinking mathematical abilities [1].

Self-efficacy (SE) in this study is interpreted as students' self-confidence in solving mathematical problems given. Similar with opinion [9,10,11] SE is defined as beliefs that focus on one's abilities in understand and solve problems in certain situations. The SE indicators are summarized from [12,13] as follows: (a) Able to overcome the mathematical problems given; (b) Know yourself in solving math problems; (c) Persistence in solving mathematical problems; (d) Dare to take risks in making decisions; (e) Commitment in completing the tasks assigned; (f) Interact positively with everyone; and (g) Not give up easily in solving mathematical problems given.
SE is one of the important soft skills students have. SE will determine how much effort students have in learning and influence the learning outcomes, and these students tend to have the potential to succeed through the right actions. This is consistent with the results of the research of several experts [9,14,15,16,17] which are summarized as follows: students face a variety of challenges, and encourage students to face a cooperative attitude, help, and share in social life, and generally, SE affects a person in making decisions and thought patterns. Students are said to have a high SE can be seen when faced with mathematical problems. [10] Claim that someone who has high efficacy in their abilities is likely to be more successful than those who have low self-efficacy.

Mathematical critical thinking skills (MCTS) is another ability discussed in this study. MCTS, according to [18,19] is the ability of a reflective and reasonable thinking process that focuses on concluding according to what is believed and what actions to take. Similar with [20,21,22,23] MCTS is one of high order thinking skills that involve several abilities others such as knowledge, logical thinking, proof in mathematics, and thinking accompanied by reasons that can be justified or can be said to be complex intellectual activity. The MCTS indicators in this study are summarized from [24,25,26,23] as follows: (a) Analyzing and considering the available information from a problem; (b) Understand and focus on problems, analyze and clarify questions, answers, and arguments; (c) Give a simple explanation but still make sense; (d) Determine strategies or problem solving tactics; and (e) Detect information or steps that are lacking or excessive in solving problems or conclusions.

MCTS is one of the important mathematical hard skills and must be achieved by students. This is similar to the results of the study [25,27,28,29] reported that MCTS among them could train the ability to think logically, systematically, carefully, objectively, and openly. In the process of developing MCTS, students are invited to think harder than usual in solving mathematical problems. Also, according to [30,31], MCTS can train students to combine various initial knowledge effectively so that students can solve mathematical problems appropriately, and this must be done with repeated training.

[26][19] reported the situation in the field that, mathematical connection ability, critical mathematical thinking, and students' mathematical self-efficacy are not optimal. [20] reports that some schools have not accustomed students to critical thinking in mathematics learning. There needs to be optimization in MCTS and SCS in solving various problems, especially in mathematics.

The study aims to describe the correlations of MCTS and SE based on SCS. This study is expected to contribute positively to various interested parties, especially in the field of mathematics education studies. The research questions proposed as follows: (a) What is the SCS classification of seventh-grade students based on Longeot Test and TOLT? ; (b) Is there any differences in the achievement of MCTS and SE based on SCS?; and (3) What is the relation between SE and MCTS based on SCS?

2. Method
This study method uses a quantitative approach. The subject of 25 students from the seventh grade who were determined intentionally came from one of the schools in Cimahi City that was of good quality in Indonesian education standards. The data analysis technique used is percentage calculation, average difference testing, and correlation testing at a significance level of 5%.

The instruments used in this study include logical reasoning tests in the form of the Longeot Test and TOLT, MCTS tests, and SE scales. TOLT [8] consists of 10 tests measuring five reasoning abilities, namely: controlling variables, proportional reasoning, probabilistic reasoning, correlational reasoning, and combinatorial reasoning. While the Longeot Test consists of 27 items consisting of the formal logic of proposition, formal logic of combination, and formal logic of proportional. The Longeot Test and TOLT instruments given to students are Bahasa Indonesia versions. The next instrument is an MCTS essay test consisting of 5 questions describing social arithmetic material from 5 MCTS indicators that have been validated and tested. Analysis The MCTS test results show high test validity, high test reliability, test distinguishing power in sufficient category, and test difficulty index in the medium category. The 28 item self-efficacy scale instrument consists of 14 positive statements and 14 negative statements from 7 self-efficacy indicators that have been validated and tested. Each statement on the scale of self-efficacy has a weighted value that has been determined based on a modified Likert scale, namely, statements with 4 alternative answers. The sample items of the Longeot Test, TOLT, MCTS essay tests and SE scales are presented as follows:
Sample Item of the Longeot Test

Question:
In a gym class, three groups want to play football. The first group consisted of 5 students and 1 ball. The second group consisted of 6 students and 2 balls. The third group consists of 12 students and 3 balls. Which group will you join to have the chance to catch more balls?

A. It's better to join the third group because you have more balls;
B. It is better to join the first group because it consists of fewer students;
C. It is better to join the second group because it consists of at least students associated with the ball;
D. Can't choose one group because the second group has more balls and more students than the first group, and the third group consists of the most students

Sample item of TOLT

Figure 1. The pendulum’s weight.

Question:
Suppose you will experiment to examine whether changes in the pendulum load at the end of the rope will change the pendulum's swing time. Which pendulum will you use?

A. 1 and 4
B. 2 and 4
C. 1 and 3
D. 2 and 5
E. All

Reason:
1. The heaviest load should be compared to the lightest load
2. All pendulums must be tested against one another
3. With the pendulum weighted, the pendulum length of the rope should be shortened
4. The weight of the load should be different, but the length of the pendulum strap should be the same
5. The weight of the load should be the same as the length of the pendulum strap should be different
Sample item of MCTS Essay Test

MCTS Indicator: Give a simple explanation but still make sense.

Question:
Yani chooses a pair of shoes with a 40% + 20% discount while Erna chooses with a 60% discount. The shoes they bought cost the same, which is Rp.540,000.00. Who among those who get the lowest shoe prices? Explain!

Sample item of Self-Efficacy Scale

The response is filled in by giving a sign (V) to the box, SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree. Sample item of SE is presented the Table 1.

| Statement                                                                 | Response | SA | A | D | SD |
|---------------------------------------------------------------------------|----------|----|---|---|----|
| I was nervous to answer questions about social arithmetic material        |          |    |   |   |    |
| I was able to find a new way when I got stuck solving social arithmetic   |          |    |   |   |    |
| am waiting for a friend's help when I have trouble solving social arithmetic |          |    |   |   |    |
| I can solve for myself social arithmetic questions when I have difficulty  |          |    |   |   |    |
| I am confused about choosing the method for solving social arithmetic that will be asked to the teacher |          |    |   |   |    |

3. Result and Discussion

3.1 The SCS Classification based on the Longeot Test and TOLT Scores

Participants in this study were seventh-grade students who were in the 11-13 year age range. Based on Piaget's cognitive development theory, participants are at the concrete stage of operation (7–12 years) and the formal operation stage (12– adults). Classification of SCS in this study was determined from the score of students in answering 10 items of TOLT and 27 items of the Longeot Test. In the combination of both tests, students are classified as concrete or formal if both of the tests are classified at the same stage. If the subject is classified as different on both tests, then the students are classified at the transition stage [1]. The classification criteria are attached in Table 2.

| Test Type                  | n | Concrete f | Transition | Formal f | %  | %  | %  |
|----------------------------|---|------------|------------|----------|----|----|----|
| The Longeot Test           | 25| 6          | 24         | -        | 19 | 76 |
| TOLT                       | 25| 15         | 60         | 8        | 32 | 2  | 8  |
| Combined                   | 25| 6          | 24         | 17       | 68 | 2  | 8  |
Table 2 shows that there are 2 students or 8% entering the formal stage, 17 students or 68% entering the transition stage, and 6 students or 24% entering the concrete stage. This can be interpreted that seventh-grade students are mostly in the transition stage. This finding can be used as the view that this is by Piaget's cognitive development theory where the concrete stage is around the age of 7 - 12 years and the formal stage is at the age of 12 - adults.

3.2 *Differences in the achievement of MCTS and SE Based on SCS*

The results description of MCTS and SE statistics based on SCS, where the maximum ideal score (MIS) for MCTS = 50 and MIS for SE = 112 is presented in Table 3.

**Table 3. Description of MCTS and SE score statistics based on SCS.**

| SCS               | MCTS          | SE          |
|-------------------|---------------|-------------|
|                   | n (%) | $\bar{x}$ | % MIS | SD | n (%) | $\bar{x}$ | % MIS | SD |
| Concrete Stage    | 6 (24%) | 26.67     | 53    | 10.82 | 6 (24%) | 75.17 | 67.11 | 9.35 |
| Transition Stage  | 17 (68%) | 37.06     | 74    | 5.14  | 17 (68%) | 75.84 | 67.80 | 7.25 |
| Formal Stage      | 2 (8%)   | 40.50     | 81    | 0.71  | 2 (8%)   | 79    | 70.54 | 9.90 |

Table 3 shows that the mean of MCTS scores in formal stage students was in the high category, while of the transition stage students were in the medium category, and of the concrete stage, students were in a low category. It can be said that MCTS of students in the formal stage is better than the transitional stage and MCTS of students are in the transition stage are better than the concrete stage. Another finding is the mean of SE scores of students at the formal stage higher than students at the transition and concrete stages. The mean of SE students in the formal stage, the transition stage, and the concrete stages are all in the medium category.

The interpretation is strengthened by the results of the MCTS and SE mean difference test which are attached in Table 4.

**Table 4. The results of the MCTS and SE difference mean test based on SCS.**

| Variables | SCS | $\bar{x}$ | s | Sig. Kruskal-Wallis | Interpretation | Sig (2-tailed), Mann-Whitney | Interpretation |
|-----------|-----|-----------|---|---------------------|----------------|-------------------------------|----------------|
| MCTS      | Formal | 40.50 | 0.50 |                     |                 | 0.318                         | Weak           |
|           | Transisi | 37.06 | 26.43 | 0.031               | Very Weak       | 0.022                         | Very Weak      |
|           | Transisi | 37.06 | 26.43 |                     |                 |                               |                |
|           | Kongkrit | 26.67 | 117.07 |                     |                 |                               |                |
|           | Formal | 79 | 98.00 |                     |                 |                               |                |
|           | SE | 75.84 | 52.56 | 0.829               | Very Strong     | 0.640                         | Enough         |
|           | Transisi | 75.84 | 52.56 |                     |                 |                               |                |
|           | Kongkrit | 75.17 | 87.37 |                     |                 |                               |                |

Table 4 found that there are significant differences in MCTS abilities based on SCS. The MCTS of students in the formal stage is better than transition stage students, and MCTS of students in the
transition stage is better than concrete stage students, even though they are categorized as very weak. This finding is similar with the results of the study [1] which reported that the formal stage ability is higher than the transition stage ability and the transition stage ability is higher than the concrete stage ability.

The other findings are no significant difference between SE students based on their cognitive stages. SE of students in the formal stage is no better than transitional stage students with enough categories. Likewise, with the SE of students in the transition stage is no better than the concrete stage students with enough categories.

3.3 Association Between SE and MCTS Based on SCS

Analysis of the relation between SE and MCTS based on SCS by using a partial correlation test. The results of the analysis are presented in Table 5.

Table 5. Partial - correlation analysis.

| Control Variables | SE     | MCTS  |
|-------------------|--------|-------|
| SCS SE Correlation| 1.000  | .320  |
| Significance (2-tailed) | .  | .127  |
| df                | 0      | 22    |
| MCTS Correlation   | .320   | 1.000 |
| Significance (2-tailed) | .127 | .     |
| df                | 22     | 0     |

Table 5 shows the correlation between SE and MCTS variables with the control variable is SCS, the correlation coefficient is 0.320, and it is in a low category. The significance value (2-tailed) is 0.127; this can be interpreted that the relations between SE and MCTS based on SCS is not significant.

This finding is seen from the results of the MCTS and SE scores of several students presented in Table 6.

Table 6. MCTS and SE scores of several students.

| Control Variables | SE     | MCTS  |
|-------------------|--------|-------|
| SCS Correlation    | 1.000  | .320  |
| SE Significance (2-tailed) | . | .127  |
| df                | 0      | 22    |
| MCTS Significance (2-tailed) | .127 | .     |
| df                | 22     | 0     |

Table 6 shows that there are students with low MCTS scores but high SE scores, on the other hand, students with high MCTS scores but low SE scores. The author suspects that students do not understand the scale of SE given, so students fill the scale of the SE does not match what they feel.

4. Conclusion

Based on the results and discussion, it was concluded that the SCS classification of seventh grade students based on the Longeot Test and TOLT scores was obtained 6 students or 24% in the concrete stage, 17 students or 68% were in the transition stage, and 2 students or 8% of students are in the formal stage. This means that most seventh grade students are in the transition stage. There are differences in MCTS based on SCS in a very weak category. There is no difference in SE based on SCS with enough categories. The relations of SE and MCTS based on SCS is not significant in the low category.
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