Critical thinking skills based on mathematical dispositions in problem-based learning

B E Susilo¹, D Darhim² and S Prabawanto²

¹Mathematics Department, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Indonesia
²Mathematics Education Department, Universitas Pendidikan Indonesia, Indonesia

*Corresponding author: bambang.mat@mail.unnes.ac.id

Abstract. This study aimed to describe students' critical thinking skills based on mathematical dispositions in Problem-based Learning. This study used descriptive exploratory methods with instruments: test, scale, observation, and documentation. Data was taken from 39 undergraduate students from the mathematics education study program at a university in Central Java. The indicators of critical thinking skills used were abilities in analyzing problems, concluding and giving explanation, evaluating, and choosing problem-solving strategies. The results showed that: (1) there are no students in the negative mathematics disposition group, (2) the enhancement of students' critical thinking skills in Problem-based Learning belongs to the medium category; (3) students in the low positive mathematical disposition group have marginally adequate abilities in analyzing, explaining, and choosing strategies, and adequate abilities in evaluating; (4) students in the moderate positive mathematical disposition group have adequate abilities in explaining, good abilities in analyzing and choosing strategies, and excellent abilities in evaluating; and (5) students in the high positive mathematical disposition group have good abilities in explaining and choosing strategies, excellent abilities in evaluating and analyzing. There was a trend of increasing the achievement of indicators of critical thinking skills based on mathematical disposition in Problem Based Learning.

1. Introduction

During the industrial revolution 4.0, in multinational and multicultural relations, problem-solving in the field of mathematics and also in complex problems in general, such as making a right decision from the large amount of data that has to be filtered or processed, people need skills in higher-order thinking, one of which is critical thinking skills. For this reason, all members of the community need this essential ability, namely critical thinking skills [1–3]. In the process of producing an effective thought or problem solving, critical thinking and creative thinking are needed, they are related to one another [4]. In general, the benefits of critical thinking skills include (1) helping in problem-solving, (2) giving consideration in making decisions, (3) helping to distinguish between facts and opinions, and (4) helps to be calm in solving complex problems. In learning, students with critical thinking skills can be investigated how they are in (1) making an analysis or clarification of a given problem (clarification), (2) evaluating or assessing a problem through reasons or examples (assessment), (3) making a conclusion (inference), and (4) developing problem-solving strategies (strategies) [5-6].

One of the goals of mathematics learning is to develop students' ability to think critically. The students expected to have the thinking skills that will assist them in making a strong decision to acquire new knowledge quickly, like critical thinking skills that are strongly needed in this 21st century.
Critical thinking skills in mathematics learning can be developed through problem-based learning [8–11]. Problem-based learning is defined as a learning model that empowers real problems as context, so students can work with critical thinking and problem-solving skills so that they gain important knowledge and concepts from the subject matter. Problem-based learning steps include: (1) giving problems to students by the teacher, (2) students are guided by the teacher to discuss in small groups to identify problems, (3) students work independently to prepare solutions to related problems, (4) students return to groups to exchange information, peer learning, and working together to solve problems, (5) students present the solutions they get, and (6) students are guided by the teacher, together to evaluate all their learning activities [12]. Based on the design applied in problem-based learning, in theory, students' critical thinking skills can be developed in the process of this learning model, but this process requires a long time [13].

The process of learning mathematics has a big challenge, found many types of difficulties experienced by students in learning it. Lecturers have tried to solve this problem by choosing appropriate learning strategies from various models, methods, and learning media. Students are motivated by lecturers so that they have a positive attitude towards mathematics. Positive attitudes towards mathematics that are expected to be owned by students include self-confidence, perseverance, interests, good judgment and appreciation of mathematics, these positive attitudes towards mathematics are indicators of mathematical disposition [14]. Students who have a positive mathematical disposition such as self-confidence and high interest, strong perseverance, and a good assessment of mathematics will help students overcome various types of difficulties they face. This is because mathematical disposition has a positive effect on students' ability to solve problems [15-19]. And vice versa if students have a negative mathematical disposition. Positive mathematical disposition of students helps overcome student difficulties and improve critical thinking skills so students can solve problems.

Based on the background that has been described, the problem in this study is focused on how to describe students' critical thinking skills based on mathematical dispositions in Problem-based Learning.

2. Method
The method used in this research is descriptive exploratory. The instruments used include tests, scales, observations, and documentation. The research data was taken in the academic year 2018/2019, conducted at one of the universities in Central Java, with a total of 39 undergraduate students from the mathematics education study program.

In this study, the scale instrument was used to measure students' mathematical disposition and group them according to categories as in Table 1. This scale has a reliability index of 0.714 and consists of 26 statement items, the scores that students can achieve are the lowest score of 26 and the highest score of 130.

| Scores         | Mathematical Dispositions Categories |
|----------------|--------------------------------------|
| 26.00 ≤ x ≤ 43.33 | High                                |
| 43.33 < x ≤ 60.67 | Negative                             |
| 60.67 < x ≤ 78.00 | Low                                 |
| 78.00 < x ≤ 95.33 | Low                                 |
| 95.33 < x ≤ 112.67 | Positive                            |
| 112.67 < x ≤ 130.00 | High                               |

In this study, the test instrument was used to find out the enhancement of students' critical thinking skills through pretest and posttest. This test has a reliability index of 0.702 and consists of four items to measure the achievement of indicators of students' critical thinking skills. The four indicators of critical thinking skills used in this study include the abilities in analyzing problems, concluding and giving an explanation, evaluating, and choosing problem-solving strategies. After students are
distributed in their respective mathematical disposition groups, the students' critical thinking skills are analyzed based on the results of achievements in the pre-test and post-test, so that their enhancement can be analyzed. Students' critical thinking skills achievement are grouped by categories as in Table 2 and measurement of enhancement using normalized gain with categories as in Table 3 [20]. Lectures are documented with video. The results of observation and documentation during lectures are used to obtain a description of student learning activities. Research data analyzed and described exploratively.

### Table 2. The Achievement Categories

| Scores          | Categories         |
|-----------------|--------------------|
| 80 < x ≤ 100    | Excellent          |
| 65 < x ≤ 80     | Good               |
| 55 < x ≤ 65     | Adequate           |
| 40 < x ≤ 55     | Marginally Adequate|
| 0 ≤ x ≤ 40      | Poor               |

### Table 3. The Normalized Gain Categories

| Gain Scores | Categories |
|-------------|------------|
| 0.7 ≤ x ≤ 1 | High-g     |
| 0.3 ≤ x < 0.7 | Medium-g   |
| 0 ≤ x < 0.3  | Low-g      |

3. Result and Discussion

3.1. Student mathematical disposition and categories.

The scale instrument was used to measure students' mathematical dispositions, 39 students had filled the scale and based on the grading scale, students were grouped by category, the results of the grouping were shown in Table 4. Based on Table 4, it was known that there were no students in the negative mathematics disposition group, there were 11 students (28.21%) in the low positive mathematical disposition group, 23 students (58.97%) in the moderate positive mathematical disposition group, and 5 students (12.82%) in the high positive mathematical disposition group.

### Table 4. Student Mathematical Dispositions Categories.

| Mathematical Dispositions Categories | Number of students | Percentage (%) |
|--------------------------------------|--------------------|----------------|
| High                                 | 0                  | 0              |
| Negative                             |                    |                |
| Moderate                             | 0                  | 0              |
| Low                                  | 0                  | 0              |
| Low                                  | 11                 | 28.21          |
| Positive                             |                    |                |
| Moderate                             | 23                 | 58.97          |
| High                                 | 5                  | 12.82          |
| Total                                | 39                 | 100.00         |

Table 4 shows that all students are in the positive mathematics disposition group, this means that all students have a positive attitude towards mathematics, and this is a good asset in learning mathematics. This good result is likely because students come from mathematics education study programs. Table 4 also shows that the moderate positive mathematical disposition group had the most members with 23 students (58.97%), while the high positive mathematical disposition group had the fewest members with 5 students (12.82%).

3.2. Students' critical thinking skills based on mathematical disposition in problem-based learning

Student achievement results in the pre-test and post-test are distributed and analyzed based on their respective mathematical disposition groups. Table 5 shows the results of the achievement and
enhancement of students' critical thinking skills based on mathematical disposition in Problem-based Learning.

Based on Table 5 it is known that the achievement of critical thinking skills based on mathematical dispositions in Problem-based Learning has an average of 30.83 on pre-test and 67.50 on post-test, with the highest achievement of 65.00 on pre-test and 100.00 on post-test, and the lowest achievement of 10.00 on pre-test and 42.50 on post-test. The average achievement of the test in the mathematical disposition groups from low to high has increased, so it can be said that based on mathematical disposition, students' critical thinking skills have increased. Based on the post-test results, sequentially, from the low positive mathematical disposition group, moderately positive, and high positive obtain an average of achievement of critical thinking skills of 50.23 (marginally adequate), 71.85 (good), and 79.00 (good). The enhancement of students' critical thinking skills in Problem-based Learning belongs to the medium category (N-Gain = 0.53). Sequentially from the low positive mathematical disposition group, moderately positive, and high positive obtained N-gain of 0.36, 0.58, and 0.66 (medium category). Based on the results of the analysis of Table 5, it can be concluded that students' mathematical disposition has a positive effect on the achievement and enhancement of students' critical thinking skills. This finding is relevant to previous research which states that Problem-based Learning is used in the development of critical thinking skills [8–11], specifically in achievement of critical thinking skills [21-22] and in enhancement of critical thinking skills [23–24].

### Table 5. Students' Critical Thinking Skills Based on Mathematical Disposition in Problem-based Learning.

| Mathematical Dispositions Categories | Number of students | Percentage (%) | Statistics Pre-test | Post-test | N-Gain |
|-------------------------------------|--------------------|----------------|---------------------|----------|--------|
| Low                                 | 11                 | 28.21          | Average : 23.64     | 50.23    | 0.36 (Medium) |
|                                     |                    |                | Highest : 40.00     | 85.00    |
|                                     |                    |                | Lowest : 10.00      | 42.50    |
| Positive                            | 23                 | 58.97          | Average : 33.04     | 71.85    | 0.58 (Medium) |
| Moderate                            |                    |                | Highest : 65.00     | 100.00   |
|                                     |                    |                | Lowest : 10.00      | 52.50    |
| High                                | 5                  | 12.82          | Average : 36.50     | 79.00    | 0.66 (Medium) |
|                                     |                    |                | Highest : 42.50     | 100.00   |
|                                     |                    |                | Lowest : 27.50      | 47.50    |
| Total: 39                           | 100.00             |                | Average : 30.83     | 67.50    | 0.53 (Medium) |
|                                     |                    |                | Highest : 65.00     | 100.00   |
|                                     |                    |                | Lowest : 10.00      | 42.50    |

3.3. Achievement of Indicators of Critical Thinking Skills Based on Mathematical Dispositions

Table 6 shows students’ achievement results in the post-test of each indicator of critical thinking skills based on mathematical disposition in Problem-based Learning. The average achievement of each indicator of students’ critical thinking skills based on mathematical disposition and overall in Problem-based Learning is shown in Table 6. Based on Table 6 it is known that overall, the average achievement of indicators of students' critical thinking skills on abilities in analyzing problems, evaluating, and choosing problem-solving strategies, in the good category, respectively were obtained at 71.00, 76.00, and 67.00, while at ability in concluding and giving an explanation in the adequate category is obtained at 56.00. The average achievement indicator of students' critical thinking skills based on the mathematical disposition, is also shown in Table 6, the comparison of achievements between categories of mathematical disposition is shown in Figure 1.
Table 6. Achievement of Indicators of Critical Thinking Skills Based on Mathematical Disposition in Problem-based Learning.

| Mathematical Dispositions Categories | Analyzing problems | Concluding and giving explanation | Evaluating | Choosing problem-solving strategies | Average |
|--------------------------------------|--------------------|-----------------------------------|------------|------------------------------------|---------|
| Low                                  | 45.45 (Marginally Adequate) | 44.55 (Marginally Adequate) | 59.09 (Adequate) | 51.82 (Marginally Adequate) | 50.23 |
| Moderate                             | 77.39 (Good)       | 55.65 (Adequate)                  | 81.74 (Excellent) | 72.61 (Good)                | 71.85 |
| High                                 | 92.00 (Excellent)  | 74.00 (Adequate)                  | 82.00 (Excellent) | 68.00 (Good)                | 79.00 |
| Average                              | 71.00 (Good)       | 56.00 (Adequate)                  | 76.00 (Good)    | 67.00 (Good)                | 71.00  |

Figure 1. Achievement of Indicators of Critical Thinking Skills Based on Mathematical Disposition in Problem-based Learning
Based on Table 6 and Figure 1, it is known that (1) students in the low positive mathematical disposition group have marginally adequate abilities in analyzing, explaining, and choosing strategies, and adequate abilities in evaluating; (2) students in the moderate positive mathematical disposition group have adequate abilities in explaining, good abilities in analyzing and choosing strategies, and excellent abilities in evaluating; and (3) students in the high positive mathematical disposition group have good abilities in explaining and choosing strategies, excellent abilities in evaluating and analyzing. The increasing trend in the achievement of indicators of critical thinking skills based on mathematical dispositions in Problem-based Learning also appears in Figure 1.

Based on the results and discussion, it can be concluded that students' mathematical disposition has a positive effect on (1) the achievement and enhancement of students' critical thinking skills and (2) the achievement in each indicator. This finding is relevant to previous research which states that mathematical disposition has a positive effect on students' ability to solve problems [15–19] and specifically on critical thinking skills [25].

4. Conclusion

Some conclusions are obtained based on the results and discussion that have been described, these conclusions include: (1) there are no students in the negative mathematics disposition group, (2) the enhancement of students' critical thinking skills in Problem-based Learning belongs to the medium category; (3) students in the low positive mathematical disposition group have marginally adequate abilities in analyzing, explaining, and choosing strategies, and adequate abilities in evaluating; (4) students in the moderate positive mathematical disposition group have adequate abilities in explaining, good abilities in analyzing and choosing strategies, and excellent abilities in evaluating; and (5) students in the high positive mathematical disposition group have good abilities in explaining and choosing strategies, excellent abilities in evaluating and analyzing. There was a trend of increasing the achievement of indicators of critical thinking skills based on mathematical disposition in Problem Based Learning. Mathematical disposition has a positive effect on the achievement and enhancement of critical thinking skills and the achievement in each indicator.

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