Critical thinking skills in integral calculus lecture based on mathematical dispositions

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Abstract. This study aimed to describe critical thinking skills in integral calculus lecture based on mathematical dispositions. This research used descriptive exploratory methods with instruments: test, scale, observation, and documentation. Data was taken from 105 undergraduate students from the mathematics education study program at a university in Central Java. Critical thinking skills are determined by using four indicators: analyzing problems, concluding and giving explanation, evaluating, and choosing problem-solving strategies. The results showed that: (1) there are no students with high and moderate negative mathematical dispositions; (2) students with low negative mathematical dispositions have poor abilities in evaluating and choosing strategies, and marginally adequate abilities in analyzing and explaining; (3) students with low positive mathematical dispositions have marginally adequate ability in analyzing, adequate abilities in explaining and choosing strategies, and good ability in evaluating; (4) students with moderate positive mathematical dispositions have adequate abilities in explaining and choosing strategies, and good ability in analyzing and evaluating; and (5) students with high positive mathematical dispositions have good abilities in analyzing, explaining, evaluating, and choosing strategies. There was a tendency of increasing achievement on indicators of critical thinking skills based on mathematical dispositions.

1. Introduction

Generally, calculus courses are taught in the Departments of Mathematics, Physics, Chemistry, Science, and Engineering. Generally, in the Mathematics Department, calculus courses are given in two semesters, namely Calculus 1 or Differential Calculus in the first semester with a weight of three credits and Calculus 2 or Integral Calculus in the second semester also weighing three credits. Calculus courses are given to provide a basic understanding of the concepts and applications of calculus theory to students [1]–[3]. Change is a special character learned in calculus. With this special characteristic calculus becomes very useful in solving problems in various fields of human life. Calculus application is used in various fields of life, such as statistics, economics, astronomy, medicine, agriculture, and others.

Calculus courses are prerequisite courses for taking the following semester courses such as Real Analysis, Differential Equations, Mathematical Statistics, and others. Students who fail in Calculus courses are not permitted to take courses that make Calculus as a prerequisite, and students who experience difficulties in some parts of Calculus are very likely to experience difficulties in the courses that make it a prerequisite.
Like mathematics in general, with great challenges in the learning process, calculus learning is expected to improve the ability to think logically, analytically, systematically, critically and creatively for students. In multinational and multicultural relations, in the era of industrial revolution 4.0, critical thinking skills as one of the higher-level skills needed in solving problems in mathematics and in complex problems, society must be able to filter large amounts of data to make intelligent decisions. Therefore, critical thinking skill is the ability that might be essential for all members of society [4]–[8]. Critical and creative thinking are interrelated with each other in producing effective thinking and solving problems [9]–[11]. In general, critical thinking has benefits in (1) solving problems, (2) helping to consider decision making, (3) differentiating between facts and opinions, and (4) calmness facing difficult problems. Through critical thinking skills can help investigate students in making an analysis or clarification of the data provided (clarification), giving an evaluation or evaluate by giving reasons or examples (assessment), making conclusions or inferences (inference), and making problem-solving strategies (strategies) [12], [13].

Besides being very useful in human life, calculus has a big challenge in the learning process, which is a lot of difficulties experienced by students in calculus learning. Some of these difficulties are in drawing graphics functions, solving infinity problems, determining what to prove, making paths or proof algorithms, and exploring the problems given, especially the problems of applying differential calculus and integral calculus. Lecturers have tried to solve the problem of difficulties in learning calculus. The solution is through learning strategies with various models, methods, and learning media, and encouraging students to have good self-confidence, perseverance, interest, judgment, and appreciation. Students are expected to have self-confidence, perseverance, and high interest and have a good assessment and appreciation of mathematics, especially calculus so that the learning difficulties they experience can be overcome. Self-confidence, perseverance, interest, judgment, and appreciation are indicators of mathematical disposition [14]. If students have a positive mathematical disposition, they are expected to be able to overcome their learning difficulties and vice versa with negative mathematical dispositions. Positive mathematical dispositions have a role or positive impact on students in solving mathematical problems [15]–[17]. With their positive mathematical dispositions, students are expected to be able to overcome the learning difficulties they face and improve the ability to think logically, analytically, systematically, critically and creatively.

Based on the background, the research problem is focused on how the description of critical thinking skills in integral calculus lecture based on mathematical dispositions.

2. Methods
This research used descriptive exploratory methods with instruments: test, scale, observation, and documentation. Data were taken from 105 undergraduate students from the mathematics education study program at a university in Central Java in the 2018/2019 academic year.

The test was used to determine the achievement of students' critical thinking skills. The test of mathematical critical thinking ability contains four items and has a reliability of 0.702. Students are classified based on the achievement of mathematical critical thinking skills as the assessment categories in Table 1. This essay test contains integral calculus problems that include antiderivative, definite integrals, application of definite integral in finding the area and the volume of a rotary object.

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

The scale was used to classify students into mathematical disposition groups. The mathematical disposition scale has a reliability of 0.714 and contains 26 items of statements. The lowest score of the
The mathematical disposition scale is 26 and the highest is 130. Students are classified based on the acquisition of mathematical disposition scale scores as in Table 2. The documentation used was video learning during lectures on integral calculus. Documentation and observation were used to obtain an overview or description of the conditions of learning and students in the integral calculus lecture. The description obtained is then developed exploratively.

### Table 2. Classification of Mathematical Dispositions.

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

### 3. Result and Discussion

#### 3.1. Results of classification of student mathematical dispositions.

Data from the results of filling the mathematical disposition scale by 105 students participating in the integral calculus are shown in Table 3. Based on Table 3, there were no students with high or moderate negative mathematical dispositions, students who were classified as low negative mathematical dispositions were 4 students (3.81%), students with low positive mathematical disposition were 41 students (39.05%), students with moderate positive mathematical dispositions were 49 students (46.67%), and students with a high positive mathematical disposition were 11 students (10.47%).

### Table 3. Results of Classification of Student Mathematical Dispositions.

| Classification of Mathematical Dispositions | Number of students | Percentage (%) |
|---------------------------------------------|--------------------|----------------|
| High                                        | 0                  | 0              |
| Moderate                                    | 0                  | 0              |
| Low                                         | 4                  | 3.81           |
| Low                                         | 41                 | 39.05          |
| Positive                                    | 49                 | 46.67          |
| Moderate                                    | 11                 | 10.47          |
| Total                                       | 105                | 100.00         |

Table 3 shows that the group of students with moderate positive mathematical dispositions had the highest percentage of 46.67% with 49 students, while the group of students with low negative mathematical dispositions had the lowest percentage of 3.81% with 4 students. Table 3 also shows that there were no students with high or moderate negative mathematical dispositions. Based on Table 3, overall students have a tendency to have positive attitudes, especially good positive mathematical dispositions, this is likely due to students having chosen mathematics as a major in college.

#### 3.2. Achievement of critical thinking skills based on mathematical disposition

Data on the achievement of critical thinking skills from subsequent test results are distributed based on students’ mathematical dispositions. Achieving critical thinking skills based on mathematical dispositions are shown in Table 4.

Table 4 shows that the achievement of critical thinking skills in the integral calculus course has an average of 62.57, with the highest achievement of 97.50, and the lowest achievement of 25.00. Based on the mathematical disposition of students, there is an increase in the achievement of critical thinking skills which can be seen from the increase in the average. Sequentially groups of students with low
negative mathematical dispositions, positive low, moderate positive, and high positive obtain an average achievement of critical thinking skills of 45.62 (marginally adequate), 58.05 (adequate), 65.36 (good), and 73.18 (good). Based on Table 4, it can be seen that mathematical dispositions have a positive role in achieving critical thinking skills.

### Table 4. Achievement of Critical Thinking Skills Based on Mathematical Disposition.

| Classification of Mathematical Dispositions | Number of students | Percentage (%) | Statistics       |
|---------------------------------------------|--------------------|----------------|-----------------|
| Negative                                    | Low                | 4              | 3.81            | Average: 45.63 |
|                                             |                    |                | Highest: 77.50  |
|                                             |                    |                | Lowest: 25.00   |
|                                             | Low                | 41             | 39.05           | Average: 58.05 |
|                                             |                    |                | Highest: 97.50  |
|                                             |                    |                | Lowest: 32.50   |
| Positive                                    | Moderate           | 49             | 46.67           | Average: 65.36 |
|                                             |                    |                | Highest: 97.50  |
|                                             |                    |                | Lowest: 37.50   |
|                                             | High               | 11             | 10.47           | Average: 73.18 |
|                                             |                    |                | Highest: 95.00  |
|                                             |                    |                | Lowest: 40.00   |
|                                             | Total: 105         | 100.00         | Average: 62.57  |

### 3.3. Achievement of Indicators of Critical Thinking Skills Based on Mathematical Disposition

The distribution of the results of achieving critical thinking skills on each indicator based on students’ mathematical dispositions is shown in Table 5.

### Table 5. Achievement of Indicators of Critical Thinking Skills Based on Mathematical Disposition.

| Classification of Mathematical Dispositions | Achievement of Indicators of Critical Thinking Skills and Its Categories |
|---------------------------------------------|-----------------------------------------------------------------------|
|                                             | Analyzing problems (Marginally Adequate) 52.50 | Concluding and giving explanation (Adequate) 50.00 | Evaluating (Margiually Adequate) 40.00 | Choosing problem-solving strategies (Adequate) 40.00 | Average (Adequate) 45.62 |
| Negative                                    | Low (Margiually Adequate) 52.20 | Adequate 55.61 | High (Good) 67.76 | High (Good) 80.00 | High (Adequate) 63.12 |
|                                             | Low (Margiually Adequate) 55.61 | High (Adequate) 66.59 | High (Adequate) 66.59 | High (Adequate) 66.59 | High (Adequate) 66.59 |
| Positive                                    | Moderate (Good) 67.76 | High (Adequate) 73.57 | Moderate (Adequate) 64.29 | Moderate (Adequate) 69.09 | Moderate (Adequate) 73.18 |
|                                             | High (Adequate) 80.00 | High (Adequate) 70.91 | High (Adequate) 69.09 | High (Adequate) 73.18 | High (Adequate) 73.18 |
| Average                                     | (Adequate) 63.12 | (Adequate) 58.51 | (Adequate) 62.77 | (Adequate) 57.80 | (Adequate) 57.80 |

Table 5 shows the data on the average achievement of critical thinking skills at each indicator in the course of integral calculus both overall and based on the students’ mathematical dispositions. Based on Table 5 the overall average achievement of critical thinking skills in each indicator in the adequate category, among others, on the indicator of analyzing problems of 63.12 (adequate), on the concluding and giving explanation indicators of 58.51 (adequate), on the evaluating indicator of 62.77 (adequate),
and the choosing problem-solving strategies indicator is 57.80 (adequate). Table 5 also shows the average achievement of critical thinking skills on each indicator based on students’ mathematical dispositions, the comparison of achievements based on mathematical dispositions is shown in Figure 1.

Table 5 and Figure 1 show that (a) students with low negative mathematical dispositions have poor abilities in evaluating and choosing strategies, and marginally adequate abilities in analyzing and explaining; (b) students with low positive mathematical dispositions have marginally adequate ability in analyzing, adequate abilities in explaining and choosing strategies, and good ability in evaluating; (c) students with moderate positive mathematical dispositions have adequate abilities in explaining and choosing strategies, and good ability in analyzing and evaluating; and (d) students with high positive mathematical dispositions have good abilities in analyzing, explaining, evaluating, and choosing strategies. Figure 1 also shows there was a tendency of increasing achievement on indicators of critical thinking skills based on mathematical dispositions. The tendency of increasing is shown by the average of achievement, at almost all levels of higher mathematical disposition had higher average achievement in almost all indicators of critical thinking skills, so that the graph tends to increase. Overall, based on the results and discussion, it can be concluded that mathematical dispositions have a positive role in achieving critical thinking skills both overall and in each indicator [15]–[17].

Figure 1. Achievement of Indicators of Critical Thinking Skills Based on Mathematical Disposition
4. Conclusion
Based on the results and discussion, there are conclusions as follows: (1) there are no students with high and moderate negative mathematical dispositions; (2) students with low negative mathematical dispositions have poor abilities in evaluating and choosing strategies, and marginally adequate abilities in analyzing and explaining; (3) students with low positive mathematical dispositions have marginally adequate ability in analyzing, adequate abilities in explaining and choosing strategies, and good ability in evaluating; (4) students with moderate positive mathematical dispositions have adequate abilities in explaining and choosing strategies, and good ability in analyzing and evaluating; and (5) students with high positive mathematical dispositions have good abilities in analyzing, explaining, evaluating, and choosing strategies. There was a tendency of increasing achievement on indicators of critical thinking skills based on mathematical dispositions. Mathematical dispositions have a positive role in achieving critical thinking skills both overall and in each indicator.

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