Enhancing students’ critical thinking skills through critical thinking assessment in calculus course

Zulfaneti¹, S Edriati¹ and Mukhni²

¹STKIP PGRI Sumatera Barat, Jl. Gunung Pangilun Padang, Indonesia
²Universitas Negeri Padang, Air Tawar Padang, Indonesia

E-mail: zulfaneti@gmail.com

Abstract. This study aims to determine the development of students' critical thinking skills through the implementation of critical thinking instruments in Calculus lectures. The instruments consist of observation sheets, critical thinking test, self-assessment, peer assessment and portfolio. The research was a qualitative research; with the participants were 53 first-year students who take Integral Calculus in Mathematics Education Department STKIP PGRI Sumatera Barat representing high-ability students, medium and low. The data in this study were collected by tests, interviews, observations and field notes. Data were analyzed descriptively; data reduction, data presentation, and conclusions. For testing the validity of data, it was used credibility test data by increasing persistence and triangulation. The results showed that in high-level students there is a change of ability from Critical enough to Very Critical, in the students with moderate and low ability there is a change of ability from Uncritical to Critical. So it can be concluded that the assessment instruments have a good contribution and can improve the ability of critical thinking.

1. Introduction

Assessment is very important to measure achievement of learning objectives. Assessment and learning process is a unity in the achievement of learning objectives that reflected in the knowledge, skills, and attitudes that are not mutually exclusive. Especially for mathematics, the purpose of learning mathematics is achieved or skills expected, namely: (1) mathematical communication; (2) mathematical reasoning; (3) mathematical problem solving; (4) mathematical connections; and (5) the formation of positive attitudes to mathematics. In order for this learning objective to be achieved, assessment is a very important role to measure the achievement. Assessment or activity assessment is an important aspect learning [2]. In addition, assessment can improve the quality of the learning process and outcomes [12], so the quality of good learning should be followed by a good assessment strategy as well because the information from the assessment is useful for improving the quality of learning [13]. Similarly, delivered by [9] that in the field of mathematics education, we have growing tendencies that emphasize the development of thinking skills and is an essential skill for life in the Information Age.

Critical thinking is a synonym of decision making, strategic planning, scientific process, and problem-solving. Critical thinking is an attempt to deepen the consciousness and intelligence of comparing some of its problems to produce a conclusion and ideas that can solve the problem. Everyone has a different mindset. However, if everyone is able to think critically, the problems they face will be simpler and easier to find solutions. Critical thinking implies a process of evaluation or
decision-making which is full of consideration and is carried out independently. Cabera in [6] states that teaching and developing critical thinking skills should be viewed as something that is urgent and cannot be underestimated. Mastery of critical thinking skills is not enough to serve as an educational goal alone, but also as a fundamental process that allows students to overcome future uncertainties.

Critical thinking skills are among the higher-order thinking skills [1]. Critical thinking has several characteristics as suggested by Wade in [7] which identifies eight critical thinking characteristics, which include: (1) Activity formulating questions, (2) Limiting problems, (3) Testing data, (4) Analyze various opinions and biases, (5) Avoid very emotional considerations, (6) Avoid oversimplification, (7) Consider various interpretations, and (8) Tolerate ambiguity. Based on the critical thinking criteria expressed by [7] it can be expressed that a person has been critical if they already have a clear flow of thinking that is a scientific thinking line that starts from formulating questions, limiting problems and avoiding errors as small as possible. So someone who is critical is someone who is able to argue with clear and definitive data and must be able to consider the decision to be taken.

One way to achieve the skills is by improving critical thinking skills. The basics teaching that can support that goal, one of them, are the Calculus. After this goal is achieved, students are expected to more easily study math on other subject based on Calculus as a tool. This goal is a unity reflected in the knowledge, skills, and attitudes that are not mutually exclusive. curriculum assessment should include the aspect of knowledge, skills, and attitudes intact and proportional [10]. This means that the learning assessment should be able to evaluate each student's knowledge, skills, and attitudes (cognitive, affective and psychomotor). So, aspects that focus only on cognitive judgments are deemed irrelevant to the curriculum. Therefore, an assessment is required that not only focuses on cognitive assessment but also touches affective and psychomotor assessments. Lecturers as evaluators in learning need to evaluate the process implemented in the classroom. The quality of good learning should be followed by a good assessment strategy as well because information from the assessment is useful for improving the quality of learning [13]. In addition, a few papers refer to using classroom assessment to establish a harmonious classroom environment and to promote students’ confidence, in fact that the purpose is to find students’ strengths during their learning process, to give encouragement, and to create a harmonious environment for teaching and learning, to find students’ strengths during their learning process, to give encouragement, and to create a harmonious environment for teaching and learning [16]. Also [8] the classroom assessment in Mathematics is among an instructor’s most essential educational tool. When properly developed and interpreted, assessments can help teachers better understand what their students are learning. So, assessment is a key component of all educational systems [11].

Assessment by [15] is defined as a process of collecting data and or information (including in the processing and documentation) systemically about an attribute, person or object either in the form of qualitative or quantitative data about the number, condition, ability or progress of an attribute, objects or persons/individuals assessed without reference to value judgment.

Assessments conducted in conventional learning generally only reveal what students know, whereas class-based assessments aim to reveal what is known and what learners can do. Through this assessment, educators not only get a picture of students' understanding of mathematical concepts that have been studied. More than that educator can express students' attitudes and motivation to the lessons and mathematical abilities.

Efforts to improve the quality of learning can be done through the model of learning and how the applied assessment mathematics. This is actually one of the factors that determine student achievement. Another factor in learning mathematics is the factor of within each student in this case of critical thinking, and significantly improve 2nd graders' mathematics achievement, including for children living in poverty, by using assessment data to individualize the mathematics instruction they receive [5]. Therefore, the study aims to determine the development of students' critical thinking skills through the implementation of the critical thinking assessment instrument in the calculus subject.
2. Methods
This research applies mix method, that is a combination of quantitative and qualitative research. The instruments used were observation sheets, tests, interview guides, and field notes. The observed indicator refers to a critical thinking indicator consisting of 6 indicators. Observations, interviews, and field notes are used to support the data found through critical thinking test results.

Research begins by observing classes that use assessment instrument. Aspects focus in observation are 1) attention to teaching lecturers, 2) ability to ask and express opinions, 3) courage to correct, and 4) pay attention to word/criticism and respect others. In addition to that observation also noted a variety of unique things in the field notes. These four aspects are shown in Table 1.

| Aspects               | Indicators                                                                 |
|-----------------------|-----------------------------------------------------------------------------|
| Attentions            | All attention is directed to material explanations                         |
| Asking and opinion    | Ask friends or lecturers about how to work/solution a topic or problem, the questions asked are relevant to the topic of learning, answering questions according to the intent and purpose of the question, or giving an argumentative opinion/response |
| Correcting            | Dare to correct other people's wrong answers                                |
| Giving and appreciate| Respond to what friends say, including positive criticism, pay attention to what a friend is doing (listening), or admitting mistakes |

Techniques of collecting data through observation was observers doing observations in a place that may be able to see all the activities of students, every 5 minutes, observers observing dominant student activity, and 30 seconds later observers write the results of observations by providing assessment Good (B), Enough (C) or Less (K) on observed activity. Observers involved in the research are as many as 5 people each responsible for observing 5-7 students. In every implementation in the classroom, open interviews are also conducted to each subject involved especially to the representative student. This interview is useful to complement/ensure data observation activities in the classroom. The grid of the interview guide is presented in Table 2.

| Aspects | Aims                                                                 |
|---------|-----------------------------------------------------------------------|
| Reason  | Knowing the reason of the subject to do something about learning, for example why want to ask, why should pay attention to teacher explanations or why should write something. |
| Aim     | Knowing the purpose of doing something both orally and in writing related to critical thinking during learning. |
| Opinion | Request opinions or suggestions about using an assessment instrument. |

Every use of the device on learning ends with a critical thinking test. The test is done three times, with the test indicator shown in Table 3.

| Indicator          | Aim                        |
|--------------------|----------------------------|
| Identify assumptions| To know student critical |
Formulate the main problem
Determining the consequences of a given provision
Detect bias
Uncover data / concepts / definitions / theorems in solving problems
Evaluate the relevant arguments in solving the problem

The results of the observations were analyzed by assigning values 3 for observations B, 2 for C and 1 for K. Tests The ability of critical thinking was analyzed with the rubric of critical thinking in Table 4.

Table 4. The Rubrics of Critical Thinking Test

| Indicator                              | Score |
|----------------------------------------|-------|
| Identify assumptions                   | 0     |
|                                        | 1     |
|                                        | 2     |
|                                        | 3     |
| Formulate the main problem             | Not at all able to formulate the main problem |
|                                        | Not able to formulate the main problem but already leads |
|                                        | Be able to formulate the main problem but are still not exact one |
|                                        | Be able to formulate the main problem correctly |
| Determine the consequences of a given provision | Not at all able to determine the consequences of a given provision |
|                                        | Not able to determine the consequences of a given provision but already leads |
|                                        | Be able to determine the consequences of a given provision but are still not exact one |
|                                        | Be able to determine the consequences of a given provision correctly |
| Detect bias                            | Not at all able to detect bias |
|                                        | Not able to detect bias but already leads |
|                                        | Be able to detect bias but are still not exact one |
|                                        | Be able to detect bias correctly |
| Uncover data / concepts / definitions / theorems in solving problems | Not at all able to uncover data / concepts / definitions / theorems in solving problems |
|                                        | Not able to uncover data / concepts / definitions / theorems in solving problems but already leads |
|                                        | Be able to evaluate the relevant arguments in solving the problem but are still not exact one |
|                                        | Be able to evaluate the relevant arguments in solving the problem correctly |
| Evaluate the relevant arguments in solving the problem | Not at all able to evaluate the relevant arguments in solving the problem |
|                                        | Not able to evaluate the relevant arguments in solving the problem but already leads |
|                                        | Be able to evaluate the relevant arguments in solving the problem but are still not exact one |
|                                        | Be able to evaluate the relevant arguments in solving the problem correctly |

This rubric (see Table 4) is developed again based on the needs of each given test item so as to provide an accurate description of the assessment. Scores obtained by students are converted into 4 criteria, i.e. are shown in Table 5.

Table 5. The Criteria of Critical Thinking

| Observation score | Test Score | Criteria         |
|-------------------|------------|------------------|
| 2.51 - 3.00       | 2.26 - 3.00| Very Critical (VC)|
The results of observation, interview and test are described and combined, and then look at the development of each critical thinking ability in each group (High, Medium, and Low) and taken conclusions.

3. Result and Discussion
Observation result of observation of critical thinking of student on calculus lecturing showed that by using the critical thinking evaluation instrument, the ability of high group increased from criteria of EV to VC, whereas in medium and the low group did not experience significant change that remained at criteria EC. Observation result of ability thinking the criteria is shown in Table 6.

| Aspect                  | High Group | Medium Group | Low Group |
|-------------------------|------------|--------------|-----------|
|                        | I          | II           | III       | I          | II           | III       | I          | II           | III       |
| Attentions             | 3.00       | 3.00         | 3.00      | 3.00       | 2.80         | 2.00      | 2.00       | 3.00         | 1.50      |
| Asking and opinion     | 3.00       | 3.00         | 3.00      | 1.80       | 2.00         | 2.33      | 1.50       | 2.50         | 1.00      |
| Correcting            | 1.50       | 1.50         | 3.00      | 1.20       | 1.00         | -         | 0.75       | -            | -         |
| Giving and appreciate | 2.25       | 1.50         | -         | 3.00       | 3.00         | 1.00      | 3.00       | -            | -         |
| Average                | 2.44       | 2.25         | 3.00      | 2.20       | 2.00         | 2.11      | 2.06       | 2.00         | 2.00      |
| Criteria               | EC         | EC           | VC        | EC         | EC           | EC        | EC         | EC           | EC        |

From Table 6, it can be seen that the use of evaluation instrument of critical thinking can invite students to pay attention to learning that is all attention is directed to a material explanation. In High Groups, from the beginning of the use of the device, the attention has a value of 3.00 (Very Good), while in the medium and low groups there is little change but still on the EC hose. For the observation of the High Group "Asking and opinion" from the initial use of observations continues to contribute very well, while in the medium-use group the device provides increased activity to ask and dispel opinions although not significant, as well as in the low-use group of assessment tools has not provided a change Which means to improve the ability to ask questions and express opinions. For aspects of correcting, and giving and appreciating, the use of assessment instrument has not had a meaningful effect, this means that the device has not contributed well to improving the response to positive criticism, paying attention to what others are saying and admitting mistakes.

The result of the observation of critical thinking ability shows that based on the predicate of students' critical thinking ability, students' critical thinking ability in High Group is categorized as Very Critical (VC), while in Medium and Low Group is categorized as Enough Critical (EC). This implies that in the Higher Group, the use of an assessment can improve attention, increase motivation to ask questions and express opinions, to correct errors and admit mistakes. While in the middle and low groups, the use of an assessment can only improve the ability of critical thinking in the category EC.

| Indicator                | High Group | Medium Group | Low Group |
|--------------------------|------------|--------------|-----------|
| Identify assumptions     | 1.13       | 2.00         | 2.38      | 0.30       | 1.67         | 1.90      | 0.38       | 1.25         | 1.38      |
| Criteria                          | EC | NC | VC | NC | NC | C | NC | EC | C |
|----------------------------------|----|----|----|----|----|---|----|----|---|
| Formulate the main problem       | 0.25 | 0.00 | 2.88 | 0.00 | 0.00 | 2.00 | 0.13 | 0.50 | 1.75 |
| Determining the consequences of  | 1.13 | 0.00 | 2.75 | 0.70 | 0.00 | 2.47 | 0.50 | 0.00 | 2.58 |
| a given provision                | 0.44 | 0.00 | 1.00 | 0.15 | 0.00 | 1.87 | 0.50 | 1.50 | 2.00 |
| Detect bias                      | 2.08 | 0.00 | 1.75 | 1.27 | 0.00 | 1.80 | 1.50 | 0.00 | 1.00 |
| Uncover data / concepts /        | 2.50 | 0.00 | 3.00 | 1.60 | 0.00 | 2.20 | 1.00 | 2.25 | 1.42 |
| definitions / theorems in solving|      |    |    |    |    |    |    |    |    |
| problems                         |      |    |    |    |    |    |    |    |    |
| Evaluate the relevant arguments  |      |    |    |    |    |    |    |    |    |
| in solving the problem           |      |    |    |    |    |    |    |    |    |
| **Average**                      | 1.26 | 0.33 | 2.29 | 0.67 | 0.28 | 2.04 | 0.67 | 0.92 | 1.69 |

The results of the I test show that in the High Group the average score of 1.26 which is included in the Enough Critical criteria (EC), the best value is given to evaluate the argument and the lowest value is the ability to formulate the main problem. In Test II, critical thinking has decreased and belongs to the category Not Critical (NC), it happens because almost all students in the High group are not able to complete the critical thinking skills test on the indicators formulate of the main problem, determine the effect of a provision, detect bias, reveal Data and evaluate arguments, only on identifying the assumptions of high-ability students capable of completing them. In Tests III, students’ critical thinking skills of High students experienced a good improvement, almost all indicators can be solved well, the average obtained by the high group in Test III is 2.29 which included in criteria Very Critical (SK). The average value of Test I in the Medium Group is 0.67 which is included in the Non-critical criteria. The lowest score is the indicator formulates the main issues and the highest in the evaluation of the argument, as well as in the second test, almost the same as the High group almost all indicators cannot be properly resolved. However, in Tests III, the average value of the moderate group was 2.04 which included in the Critical (K) criterion. This means that there is a good change to students’ critical thinking skills. The test results in the low group changed, the test I, Tests II, and Tests III, respectively, the low group obtained a value of 0.67; 0.92 and 1.69 are included in the criterion Not Critical (NC), Enough Critical (EC) and Critical (C). So, in the low group, the use of critical thinking assessment tools provides a good influence on the development of students’ critical thinking skills.

Decreasing Test II results in High and Low groups are influenced by the level of questions given and also reduced exercise. This is consistent with that found by [9] which states that students' critical thinking can be successfully encouraged and developed in basic mathematics education with content selection (task), but this result is also influenced by the attitude of students in learning mathematics, it is relevant to result [4] that state is the Students’ Emotional Life and Their Attitude toward Mathematics Learning.

The results of interviews with students, the use of assessment instrument make them more careful and increase accuracy to understand the problem. Especially must know the reason statement or argumentative opinion of the solution to the problem that is faced, so student in solving problem given more emphasis to focus attention on explanation, also student stated that in their work duty more raise attention and think deep to take action against Solving problems, and also better understand the purpose of doing something. This is certainly very influential on improving students' critical thinking in learning Calculus. Recognizing the weaknesses and the advantages of the assigned tasks gives a positive effect on the subsequent tasks, this is in accordance with the results of research [3] which states providing diagnostic feedback improves math test scores. In addition, Tran, Ho, Mackenzie and Le [14] findings indicate that the ACLC effectively supported the teachers in their preparation and implementation of teaching for creativity at these Vietnamese secondary schools. Findings also indicate that specifically guiding the teachers in how to use the ACLC and giving them prompt feedback on their teaching for creativity is helpful in promoting teaching for creativity.

4. Conclusion
The results showed that in high-level students there is a change of ability from Critical enough to be Very Critical, in the students with moderate and low ability there is a change of ability from Uncritical to Critical. So, it can be concluded that the assessment instruments have a good contribution and can improve the ability of critical thinking.

References
[1] Aktaş G S and Ünlü M 2013 Critical Thinking Skills of Teacher Candidates of Elementary Mathematics. Procedia - Social and Behavioral Sciences 93 831 – 835
[2] Mahadaniar A G, Siswaningsih W and Nahadi 2013 Jurnal Penelitian dan Evaluasi Pendidikan 18 2 pp 245–252
[3] Betts J R, Hahn Y and Zau A C 2017 Journal of Urban Economics 100 54-64
[4] Colomeischi A A and Colomeischi T 2015 Procedia - Social and Behavioral Sciences 180 744 – 750
[5] Connor C M, Mazzocco M M M, Kurz T, Crowed E C, Tighee E L, Wood T S and Morrison F J 2017 Journal of School Psychology
[6] Fachhrurazi 2011 Jurnal Penelitian Pendidikan Khusus 1 76–89
[7] Hassoubah Z 2004 Developing Creativ & Critical Thingking Skill Terjemahan Bambang Suriadi (Bandung: Nuansa)
[8] Junpeng P 2012 The development of classroom assessment system in Mathematics for basic education of Thailand Procedia - Social and Behavioral Sciences 69 1965–1972.
[9] Maričića S and Špijunovićb K 2015 Developing Critical Thinking in Elementary Mathematics Education through a Suitable Selection of Content and Overall Student Performance, Procedia Social and Behavioral Sciences 180 653–659
[10] Mulyasa 2013 Pengembangan dan Implementasi Kurikulum 2013 (Bandung: PT. Remaja Rosdakarya)
[11] Sangwin C J and Köcher N 2016 Computers & Education 94 215-227
[12] Syahrul 2009 Keefektifan Penerapan Model Asesmen Autentik Terintegrasi Dalam Pembelajaran Praktikum Ft-Universitas Negeri Makassar Jurnal MEDTEK 1 2
[13] Syahrul 2010 Jurnal Penelitian Dan Evaluasi Pendidikan 10 2 pp 246–268
[14] Tran T T T, Ho T N, Mackenzie S V and Le L K 2017 Thinking Skills and Creativity 25 10-26
[15] Yusuf M 2011 Asesmen dan Evaluasi Pendidikan (Padang: Kencana)
[16] Zhao, X Van den Heuvel-Panhuizen M and Veldhuis M 2017 Studies in Educational Evaluation 52 42-54

Acknowledgments
This research project received a research grant from the Ministry of Research, Technology and Higher Education this research was supported by KOPERTIS Region X. in here, the researchers would like to express they’re thanks to Coordinator KOPERTIS Region X, chair of STKIP PGRI West Sumatera and head of Research Unit and Community Service STKIP PGRI West Sumatera.