Mathematical critical thinking ability of students with realistic mathematics learning innovations with ethnomathematics (PMRE)

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Abstract. The importance of critical thinking ability is on the demands with the current curriculum which wants students to have the ability to analyze and solve problems, especially in everyday life. However, this ability is still not explored maximally by the teacher in classroom learning. Therefore, this study examines the improvement of critical thinking ability among students who obtained the PMRE approach with students who obtained conventional learning, reviewed as a whole and reviewed according to the high, medium and low mathematical initial ability categories. This research is a quasi-experimental study with nonequivalent pre-test and post-test control-group design. The data obtained were analyzed using the mean difference test namely t-test and mann-whitney. The results showed that: 1) the improvement of critical thinking skills of students who received PMRE approach as a whole was better than students who obtained conventional learning with a moderate category 2) reviewed from mathematical initial ability, increased critical thinking skills of students in the medium category who were getting PMRE learning more better than students who get conventional learning, while for high and low students who get PMRE learning is no better than students who get conventional learning.

1. Introduction
Critical thinking is an intellectual process which includes applying, analyzing, synthesizing, evaluating information, observing, reflecting, as a basis for trusting and doing something [1]. Mathematical critical thinking ability is an essential mathematical ability that is needs to be possessed by students who study mathematics. There are several reasons that underlie the statement. First, the ability to think mathematically contained in the curriculum and learning objectives of mathematics, among others: train thinking logically, systematically, critically, creatively and carefully and think objectively, open to face problems in daily life and to face the future that is always changing. Second, in critical thinking, a person is not easy to accept something he received, without knowing its origin, but he can be held accountable for his opinion accompanied by logical reasons [2]. Critical thinking is generally considered a cognitive process, a mental act, to gain knowledge [3]. An activity to reach knowledge, through which human thought activities can study objects, symptoms and events so that conclusions can be obtained as knowledge. The ability to think critically well can form rational attitudes so as to increase the ability to think critically is very necessary and important, especially in the present which is full of problems or challenges of life.
Based on observations in one school in the city of Jambi, it appears that students in learning mathematics only focus on the final results of problem solving. Likewise students' understanding of concepts is very weak. In fact, students are expected to understand the truth of a problem, then analyze why this is the solution. In addition, many students have difficulty in applying mathematics to real life situations, so mathematics learning in schools is not yet meaningful. There were compatible with PISA result in 2012, 2015 and 2018 [4,5,6] for students performance in mathematics. Indonesia participants students on mathematic with average score 375 in 2012, 386 in 2015 and 379 in 2018. The score were below the ideal average with 494, 490 and 489. So, learning for students should be meaningful assimilation. The material learned is assimilated and linked to the knowledge that students have in the form of cognitive structure. This is consistent with the meaningful learning theory [7]. Similar to this, learning is essentially a process of interaction with all situations around individuals [8]. Learning can be viewed as a process directed to the goal and the process of doing through various experiences. This fact shows that there is a real need for realistic mathematics learning that will improve students' critical thinking skills. Lots of previous research that discusses the learning of realistic mathematics and students' critical thinking skills [9, 10].

Therefore, this study chooses the Realistic Mathematics Education (RME) approach as an alternative learning. In addition, for optimal learning, innovation in realistic mathematics learning is carried out using ethnomathematics as a context in learning. This is in accordance with Turmudi's opinion [11] which says that culture-based learning is a necessity, because the emergence of mathematics is a product of human civilization and is a long process of human experience that is loaded with cultural issues. Sirate [12] states that there are five possibilities that ethnomathematics curriculum can be applied, namely (1) ethnomathematics must be designed in an appropriate and meaningful context, (2) delivered in the form of special cultural content or content that differs from general mathematical concepts, (3) subsequent concepts in ethnomathematics curriculum is building the idea that ethnomathematics is at the stage of developing mathematical thinking that is applied in the field of education, (4) the application of ethnomathematics curriculum can be part of mathematical ideas, (5) ethnomathematics curriculum is the integration of concepts and practices into student culture. In this study, the culture of Suku Anak Dalam (SAD) was introduced, which is a unique ethnic group in Jambi province. They are classified as a minority ethnic group [13]. Preliminary study of researchers found that there was a mathematical activity of the SAD community that could be applied for teaching mathematics. For example, to measure length an object, they use the term; sto, kilan and depo. Sto is a term to express the length from the tip of the thumb to the tip of the little finger. Kilan is a term to express the length from the tip of the middle finger to the elbow. Depo is a term to express the length when both hands are stretched from the fingertips of the right hand to the fingertips of the left hand and otherwise. This term can be used in linear equation material.

Based on these problems, the purpose of this study is to improve students' critical thinking ability with realistic mathematics learning to innovate with ethnomathematics.

2. Method

This study is a quasi-experimental research design with nonequivalent pre-test and post-test control group design. Sampling in this study was conducted by using purposive sampling technique. The sample in this study amounted to 64 junior high students in one school in the city of Jambi, which consisted of 32 experimental class students who were given PMRE and 32 control class students who were given conventional learning. Sampling is based on the cognitive development of middle school students who are in the transition phase from concrete operations to formal operations. This study first classifies students based on mathematical initial ability (MIA). The results obtained from both classes; 9 high ability students, 45 medium ability students and 10 low ability students. The material taught in this study is the linear equation and inequality of one variable.

The critical thinking ability test was given by the researcher before and after treatment. The indicators of critical thinking ability tests used were, namely: a) Finding facts, data, and concepts and can conclude an appropriate solution; b) Identifying what is known, asked and the adequacy of the elements in the problem, making mathematical models, planning solutions, and completing
mathematical models; c) Applying various strategies arranged and giving reasons to determine and implement these standards d) Finding and detecting important things in the problem and drawing conclusions precisely. From the pretest and postest scores obtained n-gain scores to determine the increase of students’ mathematical critical thinking ability, then the rate of improvement will be differentiated by the following classification [14]: (1) n-gain > 0.7 (high); (2) 0.3 < n-gain ≤ 0.7 (medium); (3) n-gain ≤ 0.3 (low).

3. Result and Discussion

The results in this study will be presented descriptively and using inferential statistical tests. This examination is to determine the increase in students’ critical thinking skills that obtain PMRE learning and conventional learning. Table 1 shows that overall the improvement in critical thinking skills of students who obtained the PMRE approach was better than students who obtained conventional learning. This can be seen in the average posttest score in the experimental class of 58.33 while in the control class of 44.40. In addition, the overall n-gain of students who get PMRE is 0.46 in the medium category, while the n-gain of students who get conventional learning is 0.37 in the medium category.

### Table 1. Description test of mathematical critical thinking ability.

| Mathematical Initial Ability | Stat. | Pretest | Conventional Posttest | n-gain | N | Pretest | PMRE Posttest | n-gain | N |
|------------------------------|-------|---------|-----------------------|--------|---|---------|---------------|--------|---|
| High                         | x̄    | 15.63   | 59.36                 | 0.50   | 4 | 21.67   | 67.5          | 0.58   | 5 |
|                              | s     | 12.44   | 12.44                 | 0.19   |   | 9.03    | 11.56         | 0.18   |   |
| Medium                       | x̄    | 11.17   | 42.80                 | 0.35   | 22| 22.65   | 57.43         | 0.45   | 23|
|                              | s     | 10.48   | 10.30                 | 0.12   |   | 7.19    | 11.02         | 0.14   |   |
| Low                          | x̄    | 6.25    | 40.28                 | 0.37   | 6 | 23.96   | 52.08         | 0.37   | 4 |
|                              | s     | 9.77    | 10.76                 | 0.07   |   | 3.99    | 10.49         | 0.14   |   |
| Total                        | x̄    | 10.81   | 44.40                 | 0.37   | 32| 22.67   | 58.33         | 0.46   | 32|
|                              | s     | 10.56   | 11.81                 | 0.12   |   | 7.02    | 11.54         | 0.16   |   |

To see whether an increase in the critical thinking skills of students who received PMRE learning (experimental class) was significantly better than students who obtained conventional learning (control class), a one-party difference test was conducted in Table 2. The results obtained were a significance value of 0.0165 or smaller than the significance level $\alpha = 0.05$. Thus, the conclusion obtained is an increase in the critical thinking skills of students who obtain a PMRE approach significantly better than students who obtain conventional learning.

### Table 2. The average difference in test of mathematical critical thinking ability.

| Mathematical Initial Ability | Hypothesis | Statistic Test | Sig. | $H_0$ | Interpretation |
|------------------------------|------------|----------------|------|-------|----------------|
| Total                        | Hypothesis 1 | Mann-Whitney | 0.000 | Rejected | There is an improvement |
| High                         | Hypothesis 2 | Independent Sampel t-test | 0.2865 | Accepted | There is no improvement |
| Medium                       | Hypothesis 3 | Independent Sampel t-test | 0.013 | Rejected | There is an improvement |
| Low                          | Hypothesis 4 | Independent Sampel t-test | 0.495 | Accepted | There is no improvement |
Table 3. Achievement of students’ test of mathematical critical thinking ability based on indicators.

| Learning Process | STAT. | Indicator | Total Score |
|------------------|-------|-----------|-------------|
|                  | Total Score | 1 | 2 | 3 | 4 | 12 | 24 |
| PMRE             | $\bar{x}$ | 3.812 | 1.78 | 1.46 | 3.68 | 14 |
|                  | %     | 95.31 | 59.37 | 48.95 | 46.09 | 58.33 |
| Conventional     | $\bar{x}$ | 3.28 | 1.65 | 1.14 | 1.78 | 10.65 |
|                  | %     | 82.03 | 55.20 | 38.02 | 22.26 | 44.4 |

Based on Table 3, it appears that in the four indicators of critical thinking skills used in this study, the percentage of achievement of critical thinking skills of students who learn with PMRE learning is higher than students who learn with conventional learning. When viewed from the achievement of students’ critical thinking skills compared with the ideal maximum score, it shows that the achievement of the experimental class is 58.33% while the control class is 44.4%. The achievement of the experimental class was higher than the control class. In this study, we also see an increase (N-gain) of students' critical thinking skills. N-gain critical thinking ability is obtained from the difference between the percentage difference between the posttest and pretest scores with the difference of 100% with the percentage of pretest scores. From the analysis, it was found that the average N-gain of the experimental class was 0.46 with the moderate category, and the average N-gain of the control class was 0.37 with the moderate category. The mean value indicates that the increase in critical thinking skills of the experimental class is higher by 0.09 or 9% compared to the control class.

When viewed based on the student's mathematical initial ability (MIA) category, an increase in the critical thinking skills of students who obtain the PMRE approach is better than students who obtain conventional learning in the moderate MIA group. Based on the test results of the average difference in the N-gain score between the two classes, the MIA group students were getting a significance value of 0.013 or smaller than the significance level $\alpha = 0.05$. So that the conclusion obtained is, an increase in the ability to think critically the MIA group students who are getting the PMRE approach are better than students who are getting conventional learning. Whereas in the high and low MIA group, based on the test results the difference in the average N-gain score between the two classes, in the high MIA group students obtained a significance value of 0.2865 while in the low MIA group obtained a significance value of 0.495 or greater than the significance level $\alpha = 0.05$. This means that the increase in critical thinking skills of high and low MIA group students in the experimental class is significantly no better than students who obtain conventional learning.

Based on Table 1 we can see that the average posttest of the experimental class and the control class are still relatively low at 58.33 and 44.40. Although there is an increase in the n-gain value as in table 2, it is still in the moderate category. Based on the MIA, the increase occurred only in the moderate group. While, there was no increase in the high and low groups. In this study, there are many factors that influence these results, such as: readiness of students in facing PMRE learning, knowledge of student characteristics, group division based on initial abilities that have not been effective, and preparation of research that has not been optimal. However, the PMRE approach provides a new learning experience for students regarding the realistic problem of innovating with SAD ethnomatatics.

In Table 3, we can see that the problem most difficult for students to do is problem number 3. Whereas, the easiest according to students is problem number 1. Problem number 3 with indicators applying various strategies arranged and giving reasons to determine and implement these standards expect students to be able to implement various settlement strategies and be able to give reasons. This is considered difficult for students who are accustomed to solving problems using one solution. Paradesa research also concluded that more than 50% undergraduate students of mathematics education still difficult to solve well-structured problem as long as the problem does not imitate the example that is given in learning process [15]. Therefore, the use of contextual problems and the provision of non-routine problems should become a habit for the teacher as an alternative learning.
Problem number 1 is the easiest problem for students to do. Problem indicator number 1 is finding facts, data, and concepts and can conclude an appropriate solution. This means that students have been able to find things that are known, asked and concepts in the problems needed for resolution.

This means that students' mathematical critical thinking skills still need to be trained and pursued. Critical thinking skills should be part of students' learning and schools should be responsible for developing and evaluating critical thinking skills through the teaching and learning process [16]. This is in accordance with the statement of Conley [17] "Habits of mind" such as "analysis, interpretation, precision and accuracy, problem-solving, and reasoning" can be as, or more important than, content knowledge in determining success in university courses. The teacher can provide exercises in the form of non-routine questions to students. Learning by using innovative and effective learning models also needs to be learned. The ability of prospective mathematics teacher students to teach critical thinking skills is also important to prepare. About 60% of participants believed they were prepared to teach critical thinking and generally preferred constructivists over traditional instruction. Some aspects of pre-service education were not associated with pedagogical beliefs about critical thinking disposition, perceived preparedness, or preference for constructivist instruction (and only weakly associated with associated beliefs about teaching critical thinking skills [18].

PMRE approach is an innovation of learning consisting of Realistic Mathematics Education innovation with Ethnomathematics community SAD as a context. Realistic contexts or problems are used as a starting point for this PMRE approach. Context does not have to be a real world problem but can be in the form of games, the use of visual aids, or other situations as long as they are meaningful and can be imagined in students' minds. In other activities, students are also given the opportunity to carry out measuring activities using SAD community measurement techniques known as kilan, sto and depo. Student interactions and activities in this activity make learning fun. It also shows that the ethnomathematical approach can also be used in learning.

![Student measuring the length of wall by spreading his hands (depo).](image)

In addition, there is a mathematical process in the PMRE approach called model usage. The use of the model functions as a bridge from concrete level knowledge and mathematics to formal level mathematical knowledge. This study is using scales or dancing in terms of the SAD community. This teaching aid is to facilitate students in understanding the completion of PLSV and PtLSV by adding, subtracting, dividing and multiplying by the same number. Students look enthusiastic and excited in using the teaching aids that are prepared.
For example there is a question "If the right hand side of the scale is filled with three black plastic bags containing the same number of marbles plus the seven marbles on the outside is balanced with the left hand side of the scale containing 25 marbles. So what is the number of marbles in the black plastic bag? ". Next students practice it by taking and adding marbles in accordance with the instructions. Then students try to write their mathematical models on the board, $3x + 7 = 25$. For $3x + 7$ the same as the right hand side of the scale and 25 equals the number of marbles on the left hand side. $x$ is a variable for expressing black plastic bags. This is a mathematical model of the experiments carried out. After that, here is one of the critical thinking ability test related to finding facts, data, and concepts and can conclude an appropriate solution.

Problem 1
In a party, if every 2 people get one plate of rice and every 3 people get 1 serving of meat, and the total number of dishes is 65 dishes. How many guests came to the party?

Based on Figure 3, it can be seen that students can find the facts of the questions given then find the concept of open sentences and change the questions above into mathematical sentences correctly. This shows that students have a critical ability to solve the given problem. Students also show their ability to change the form of story problems into correct mathematical sentences. Most students in the experimental class answered correctly for question no 1. The same thing happened to students in the control class, most students were able to solve this problem well. Next, Here is one of critical thinking ability test related to Identifying what is known, asked and the adequacy of the elements in the problem, making mathematical models, planning solutions, and completing mathematical models.
Problem 2
A father is 24 years older than his child. In the next 8 years the father's age will be twice the age of his child. Look for their age now!

Figure 4. The answer from a student in experiment class for question number 2.

Figure 4 shows that students are able to make a problem solving plan by assuming what is known with a variable $y$. Then proceed with completing the design with a strategy. In this case equating things that are known to find the value of the variable in question. Based on these tests and answer sheet, it was proven to have a more positive impact on improving students' critical thinking skills compared to conventional learning. This is in line with Somakim [19] the results of his study indicate that the learning approach factor provides a significant influence on increasing students' mathematical critical thinking abilities. That is, there are differences in increasing students' mathematical critical thinking skills, if students are grouped according to the learning approach. Jannah, Isrok'atun and Sunaengsih [20] concluded that the RME approach based on local culture had a positive influence on students' mathematical critical thinking abilities. These positive effects indicate that there is a significant increase in the ability to think critically mathematically. A greater increase occurred in the experimental class at 0.32 in the medium category.

4. Conclusion
Based on this study, I was able to improve the critical thinking skills of junior high school students in one school in the city of Jambi by using PMRE. The results showed that the overall increase in students' critical thinking skills by 0.46 was in the medium category. Reviewed from mathematical initial ability, increased critical thinking skills of students in the medium category who were getting PMRE learning more than students who get conventional learning, while for high and low students who get PMRE learning is no better than students who get conventional learning. From these results, I can conclude that students in the city of Jambi still have problems in terms of mathematical critical thinking skills.

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