JUNIOR HIGHSCHOOL STUDENTS' MATHEMATICAL CRITICAL THINKING ABILITY UNDER REALISTIC MATHEMATICS APPROACH

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ABSTRACT: *Now days, critical thinking is increasingly of demand. This study is concerned with a report on the superiority of the Realistic Mathematics Education (RME) approach compared to the conventional approach in teaching mathematics based on experimental research. Its superiority was shown by the outcome achieved and the process underwent by students in developing their mathematical critical thinking. The subjects of the study were Year IX of Kulisusu Junior High School, studying the topics of Congruence and Similarity. Purposive sampling, which was followed by class random, was employed. The design of the study was Pretest-Posttest Control Group Design. The study found that (1) Mathematical critical thinking of the students under RME approach was at high category. As for the aspects of analyzing algorithms they were still low, while that of identifying and justifying concepts, generalizing, and solving problems, they were well developed. (2) Mathematical critical thinking of the students studying under conventional approach were at mid level category. (3) Improvement of the mathematical critical thinking of students studying under RME was better than those under conventional approach. (4) The students responded positively to studying under RME positive, they enjoyed the process of the teaching.*

Key words: Critical Thinking; Mathematical Thinking; Realistic Mathematics

1. INTRODUCTION

The goal of teaching mathematics to all students since elementary schools is to equip them with logical, analytical, systematic, critical, and creative thinking, as well as with an ability to work cooperatively. Therefore, the teaching of mathematics should be aimed at developing three aspects of ability:(1) ability to solve problems in mathematics, other subjects, and real life; (2) ability to use mathematics as a means of communication; (3) ability to reason and applicable in any situation, such as in critical, logical, and systematic thinking, being objective, honest, and disciplined in viewing and solving problems.

The three abilities indicate how important it is to study mathematics as a basic capital in developing thinking pattern, communication, and attitude useful to societal life in our daily life, at work. These competences are required by the students that they would possess the ability to obtain, manage, and make use the information to survive in this changing, uncertain, and competitive life.

At the operational stage at school, the three abilities are embodied in the teaching of every material of mathematics. Deductive-inductive process of thinking is introduced as the primary element. Also, the logical reasoning is utilized as the processing tools for the presence of logical reasoning in every mathematical concept. Symbolic and steady language of mathematics makes it consistent in its norms and rules. Hence, communication in mathematical language is more practical, systematic, and efficient. Through this kind of teaching process, as well as the use of everyday life problems, students learn to reason, communicate, and solve mathematical problems systematically and efficiently. This helps students to form a complete, consistent personality, honesty and self-confidence.

In order to attain the goal of mathematics teaching above, it is still common that teachers in their instructions (1) elaborate mathematical concepts and operation,(2) exemplify problem solving, and (3) asking students to answer problems similar with the problems they worked on before. This way emphasizes the memorization of concepts and procedures in answering questions. This way of teaching is called mechanistic way[1]. Teachers do not emphasize the teaching of mathematics on the understanding of mathematical concepts and operations, but on the recognition of mathematical symbols with more emphasize on the provision of information and the exercises in the implementation of mathematical algorithm[14].Teachers rely on lecture method, students are passive, true answers are accepted, small number of ask-question, and students copy from a white board. This is still common at schools in Southeast Sulawesi, at Kulisusu Junior High School in particular.

The application of the mechanistic teaching of mathematics results in weak slow development of critical thinking ability of students. Students are only skillful in answering questions similar with the ones given in the classroom. When they are faced with different questions, they have difficulties to answer. In general, students' have problems to make a connection between identification and justification of concepts, algorithmic analysis, generality, and solving problem. This certainly affects the mathematics learning achievements of students.

It should be admitted that both teachers and students currently have problems in developing critical thinking in the teaching of mathematics. In general, teachers have not presented sufficient exercises to gear up the development of critical thinking, because every exercise given are just oriented to outcome ignoring the process of learning by students. In addition, students rarely trained to solve the problem of mathematical critical thinking.

Principally, critical thinking is a high level of thinking. The ability to think critically could be possessed by students to face real life problems because critical thinking is one of the bases for someone to further decisions. Critical thinking is also a mental process involving critical things, such as induction, deduction, classification, and reasoning. According to Ennis, critical thinking is a rationally reflective way of thinking or based on reasoning, in deciding what should be done and to be believed [3, 5,].

In the process of thinking, analyzing, criticizing, and drawing conclusions based on inference of careful thoughts are often in presence. By thinking critically people will understand argumentation based on different values, inference, and capable of interpreting and recognizing mistakes, capable of using language in debating, realizing, and controlling geocentricism and emotion, and responsive to different views.

Critical thinking ability is a cognitive process to gain knowledge. According to Fahroy in [4, 5, 9], the critical thinking activate the ability to analyze and evaluate evidence, identify questions, logical conclusion, to understand implication of arguments. He further argues that critical thinking is a crucial activity to be develop at schools, teachers are hoped to be able to practice instructions that activate and develop critical thinking ability of their students. If this ability is continuing to trained, it will become a habit. This habit will become the basic attitude, and in the end it will form a disposition to think critically .

In an effort to improve critical thinking ability, it should be attention to the phases of critical thinking. Garrison *et al.*[8] divide the phases of critical thinking into four: (1) *Trigger event* – identifying or recognizing an issue, problem, dilemma in one's experience, instructor's or other students' utterances, (2) *Exploration* – thinking of personal and social ideas for the preparation of decision making, (3) *Integration*–constructing the intention/meaning of the ideas, and integrating relevant information set in the previous phases, and (4) *Resolution*– proposing a hypothetical solution, or directly applying the solution to an issue, dilemma, or problem, and testing the ideas and hypothesis.

Furthermore, [5, 9] with regard to the teaching materials of mathematics subject, critical thinking ability classification should take into account: (1) aspect related to concepts, which involves identification of the characteristics of concepts, a comparison of concepts, identification of examples of concepts, and identification of contra examples of concepts, with justification; (2) aspect related to generalization, which involves decision on which concepts are part of the generalization, decision on conditions in which generalization will be applied, formulation of generalization formula and provision of evidence supporting generalization; (3) aspect related to skills and algorithm, which involves classification of conceptual base of the skills and comparison of students' performance and exemplary performance; (4) aspect related to problem solving, which involves providing common form for the purpose of solution, deciding the information given, deciding whether information is relevant or not, choosing and justifying a strategy, suggesting an alternative method and indicating similarities and differences between problem given and others.

Even though experts give different definitions of critical thinking, in principle all agrees that it refers to reflective thinking in making a decision or solving a problem. In relation to classroom instructions, particularly at junior high schools, critical thinking in this study refers to Ennis and Facione's comprising aspects of identifying and justifying concepts, generalizing, analyzing algorithm, and solving problems.

Student oriented mathematics teaching seems to be potential in training and improving students' critical thinking ability. It allows students to actively construct their own knowledge based on their existing knowledge and experiences, under adults (teachers) assistance and guidance. Teachers allow them to think and act freely to understand and solve problems. They do not simply present teaching materials, but should be good mediators and facilitators. They should provide media stimulating productive thinking of their students, opportunities and experiences supporting learning process; they should encourage students; and they also need to provide conflicting experiences [1,6].

In constructivism, students are assumed to have had ideas/knowledge of their environment and events/phenomena around them. This is in line with the view that the main thing in educational activities is to start the process from "students' existing knowledge". This enables students to construct by their own knowledge and understanding, from non-scientific ideas to scientific knowledge. Teachers become "facilitator andprovider of condition" for the process of learning to take place. Classroom interactive discussions, demonstrations of scientific procedures, and the testing of the finding in a simple observation is conducive learning condition. This kind of classroom condition will give students opportunities to ask, answer, discuss, and express ideas and concepts in systematic ways. Such a condition can make a school become a center of democratic life valuing ability, upholding justice, application of equal opportunities, and considering diversity and difference among students and environments.

In mathematics teaching, an approach which is in accordance with the philosophy above is Realistic Mathematics Education (RME) which was originally introduced in Holland in 1975, and based on the philosophy [7] viewing "mathematics as human activity and all mathematical elements in everyday life should be utilized in the teaching of mathematics in the classroom". By using contextual, everyday issues, students are faced with situations they know, so that they become motivated in using their basic knowledge of mathematics they have learned and understood.

Beside mathematizing the everyday problems, students are also given an opportunity to put concepts, notations, models, procedures, operations and solution of other mathematical problems into mathematical form. As human activity, mathematicsmaterial should be found by students themselves, and therefore, they learn to form a mathematical model (formally or not) based on the problem presented. In the end, they will form their own mathematical structures and understanding, and knowledge.

Provision of opportunities to work on mathematical problem taken from their own everyday life, using their own knowledge and experience will help students to build new understanding of concepts and mathematical operations [10]. Teachers' guidance and discussions with classmates are assistance for students to find formal model of mathematics. This is the main foundation in the formation and development of students' learning attitudes in the real sense [1,6].

According to [10], there are three main principles in RME: guided reinvention and progressive mathematization, didactical phenomenology, and self developed model.

a. Guided reinvention and progressive mathematization

The main idea of realistic education is that students should be given opportunities to reinvent mathematical concepts and principles under the guidance of adults [10]. According to this view, activities of students are important. They have to have opportunities to find mathematical concepts by themselves by working on various contextual problems. Those contextual problems lead them to form concepts, set up model, apply known concepts, andsolve them based on applicable mathematical norms. Based on the problem, they build a model based on the model of the situation of problem (formally or not), then build mathematical model for solving in so that they gain knowledge of formal mathematics.

Invention of mathematical model, concept, and procedure starts in mathematizing process in which students formulate problem structure in both formal and non formal mathematical forms. They take this step by presenting mathematical concepts and procedure they know to solve problems. Problems given are contextual problems and are intended to support reinvention process that give students opportunities to formally understand mathematics [10]. The invention process itself involves inventions and application of mathematical formal and informal models.

Progressive mathematizing can be divided into two components: horizontal and vertical mathematizing [6, 15]. In horizontal mathematizing, students identify that contextual problems should be transferred into a mathematical form to be further understood. Through scheming, formulation, and visualization, students try to find similarities and relation between problems and transfer them into the form of mathematical models they have known. These mathematical models can be formal or non formal. In vertical mathematizing, students work on formal or non-formal mathematical problems taken from contextual problems by using mathematical concepts, operations, and procedures applicable and known by students. Rules, formulations, and conditions applicable in mathematics should be applied correctly to get correct answers or results. In the end, students formulate and generalize problems by comparing answers and problem's contexts and condition. In such a case teacher's roles is very dominant. Under the assistance of teachers, students show the relation between the formulae used, prove mathematical rules applying, compare models, and formulate mathematical concepts and generalize [13].

b. Teaching Phenomena

The teaching phenomena emphasize the importance of contextual problems to introduce mathematical topics to students. In using contextual problems it is necessary to take into account the first two aspects: suitability of context for teaching and suitability of the impact in the reinvention process of mathematical forms and models of the contextual problems. Contextual problems in realistic mathematics approach function in: (1) concept formulation (to help students utilize mathematical concepts); (2) model formulation (to form mathematical basic model in supporting mathematizing thinking pattern); (3) Application (to utilize real condition as the source of application); (4) Training (to train students with special ability in real situation) [15].

In RME, students study individually or in groups to determine steps and strategies to be taken in solving contextual problems. The strategies are created and developed by students themselves (free production)in the forms of informal mathematics (diagrams, pictures, codes, symbols, etc.) andalso formal mathematics (conceptsand algorithm) they learned previously. Teachers only guide and facilitate them and become a bridge taking the informal mathematics to formal, standard mathematics.

c. Self Developed Model

Self developed model function as a bridge the gap between students' informal mathematical knowledge and their formal one. In RME, mathematical models are raised and developed by students on their own. They develop the models starting with solving contextual problems from real situation students have known, then to model of situation (informal model), followed by invention of model for the informal form (formal form), until getting problem solving in the form of standard mathematical knowledge. For the RME to take place well and the result is optimal, the teaching process should bring out the principles and characteristics of RME.

2. METHOD

This experimental study employed Pretest-Posttest Control Group Design. The population was students Year IX of Kulisusu Junior High School, in the district of Buton Utara of Southeast Sulawesi province of Indonesia. Sample was drawn by way of purposive sampling technique followed by *Random Class.* This resulted in the chosen of class IX_2as experimental class and class IX_3as control class, [2]. The design of this research can be seen in Table 1 below:

Tabel 1: Research Design

	Measurement (pre test)	Treatment	Measurement (post test)
Eksperiment group (E)	O_1	X	O_2
Control group (K)	O_3	-	O_4

Remarks:

EK = Experiment class

KK = Control class

X = Treatment, Teaching under RME-

O_1 = Pre-test of experiment class before treatment.

O_3 = Pre-testof control class before treatment

O_2 = Post-testof experiment class after treatment

O_4 = Post-testof control class after treatment.

Prior to the analysis of data, the improvement of critical thinking ability was calculated using N-gain:

$$\text{N-Gain} = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}}$$

Notes: S_{post} = post test Score = Tanpa perlakuan, pembelajaran

S_{pre} = pretest Score, and

S_{max} = Possible maximum Score

Attained by a student.with the indicator:

High, if N-Gain > 0.7

Mid, if 0.3 < N-Gain ≤ 0.7

Low, if N-gain ≤ 0.3

N-Gain was utilized to take away student's guess factor and the effect of highest score so bias conclusions could be avoided [11, 12]. N-Gain value was then analyzed with Paired Samples t-test and t-test[16] to find out the significance of the increase and the difference of the mean scores of the two groups, using level of significance $\alpha = 0.05$.

3. RESULT

The mean score of posttest on mathematical critical thinking ability of experiment class was 70.24, higher than that of the control class which was 59.52. Whereas the N-Gain mean score on mathematical critical thinking of experiment class was 0.68, higher than that of the control class which was 0.53. This indicates that the improvement of mathematical critical thinking of experiment class was better than that of control class.

In general, the quality of the improvement of mathematical critical thinking of experiment class was in the mid category as shown by the its N-gain mean score and the N-gain mean score of the control class presented in Table 2 below.

Table 2: N-Gain Mathematical Critical Thinking Data

Descriptive Statistics					
	N	Mean	Std. Deviation	Minimum	Maximum
N_GAIN_EXP	25	.68	.13653	.42	.88
N_GAIN_CONT	25	.53	.18510	.14	.75

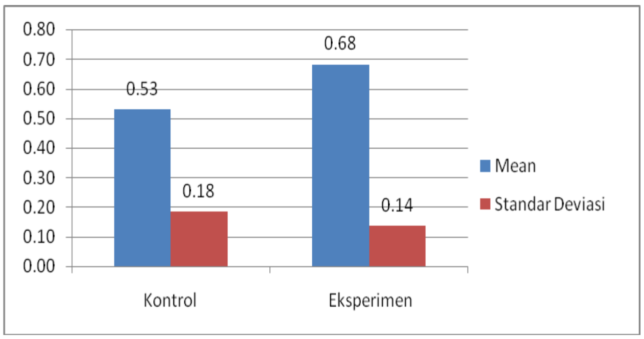

Fig 1: Mean and Standard Deviation of N-Gain of Mathematical Critical Thinking Ability of Experiment and Control Classes

The comparison between N-Gain mean and standard deviation of mathematical critical thinking between experiment and control groups is presented in the bar diagram in figure 1.

After normality and homogeneity test was done on the data of experiment class and control class, the test of significance of improvement of mathematical critical thinking ability of both experiment and control classes was done by mean of *Paired Sampels t-test.* The result of the test of significance, as shown in Table 3, was 0.000. Because the significance was smaller than 0.05, it was concluded that there was a significant improvement of mathematical critical thinking ability of the experiment class, from the result of the pretest to the posttest.

Table 3. The Result of Significance Test of Mathematical Critical Thinking Ability of Experiment Class

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRE_TEST - POST_TEST	-6.09600E1	10.72567	2.14513	-65.387	-56.532	-28.418	24	.000

The result of statistical analysis t-test (different test) of mathematical critical thinking of experiment class and that of control class, summary of the result of the analysis of t-test of the data of the two groups are presented in Table 4, and the t-count was 3.287 with the significance value of 0.002 (smaller than the significance level 0.05); it is meaning that H_0 rejected.

Looking at the four aspects of mathematical critical thinking developed under RME, students' mean score for the aspect of concept identification and justification was 3.28; for algorithm analysis was 2.92; for generalizing was 3.84; and for problem solving was 3.76 of 5.0, the maximum score.

Students' responded very positively in the teaching under RME as indicated by their answers to the questionnaires. The average percentage of students answering happy being taught under RME was 80.5%. Meanwhile, student's activities during the teaching process under RME in the first meeting was 72.8%; in the second meeting was 74.6%; in the third meeting was 77.9%; in the fourth meeting was 83.8%; in the fifth meeting was 84.8%; and in the sixth (last) meeting was 86.3%.

Table4:Test of Difference of Two Means of N-Gain of the Mathematical Critical Thinking Ability of Experiment and Control Classes

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
N_GAIN_CONT_ EXP	Equal variances assumed	3.725	.060	3.287	48	.002	.15120	.04600	.05871	.24369
	Equal variances not assumed			3.287	44.15	.002	.15120	.04600	.05850	.24390

4. DISCUSSION

The result of data analysis indicates that experiment class's mean score on the mathematical critical thinking in the posttest was 70.24 (high category), and the mean score of the control class was 59.52 (middle category). There was an increase in both experiment and control classes' mathematical critical thinking. The N-Gain means score of experiment class was 0.68 whereas that of control class was 0.53. This means that the N-Gain means score of the class taught under RME was higher than that of the class taught under conventional method.

The result of Paired Sampels t-test showed that t = -28.418 with the significance of 0.00 meaning that the improvement of the mathematical critical thinking ability of students taught under RME was significant.

The result of t-test (test of difference) showed that t = 3.287 with significance of 0.002. This means that there was a significant difference between the improvement of mathematical critical thinking of the class under RME (experiment class) and that of the class under conventional method (control class). Therefore, it can be said that teaching approach has significant effect on mathematical critical thinking ability of the students. It means that there is a difference in improvement of mathematical critical thinking ability due to the use of different teaching approaches used. Based on the average value of improvement (N-Gain) of the two classes, that is, 0.68 > 0.53, it can be said that the teaching under RME approach is better in improving mathematical critical thinking of the students compared with the teaching of mathematics under conventional approach, especially for the topics of congruency and similarity.

This is possible because in RME approach, the formation of mathematical knowledge starts from working on everyday life problems. By working on mathematical problems recognized by students and taking place in their real life, students build their mathematical concepts and understanding using their instinct, reasoning ability, and mathematical concepts they have known. They form by themselves mathematical knowledge structure under teacher's assistance by discussing possible alternative answers, in which case the most efficient answer is expected, without ignoring other alternatives [1].

The formation of mathematics understanding by working on the problem from everyday life will bring advantages for students, in the following ways: (1) students can understand more the situation, condition, and event around them. Around them are different cultures containing mathematical elements. (2) students are skillful in solving problems independently making use of his/her own capability (instinct, reasoning, logic, and science). In such case, improving "Learning for living" and "life skill" have their real portion. (3) students build their comprehension of mathematical knowledge on their own, and as a consequence, increase their self-confidence proportionally in doing mathematics. They will not be afraid of mathematics subject.

Basically RME approach focuses on reinvention the ability of students, an ability to reinvent mathematical concepts through contextual problems presented in Student Activity Sheet (Indonesian: LAS). The context developed is in accordance with the characteristics of RME containing everyday life problems. Then, from the beginning of the context informal mathematics is designed (model off), and students are expected to be able to develop or apply it in formal mathematics (model for). It is process of mathematical modeling which can improve students' mathematical critical thinking ability.

RME also trains on mathematical critical thinking. Students identify that contextual problems should be transferred into mathematical model to be further understood. Through scheming, formulation, and visualization, students try to identify the problem similarity and relation and transfer them into mathematical models they are knowledgeable of. The mathematical model can in formal or informal form [13, 14]. Here, the role of the teachers is to help students find the models by describing models suitable to present the problems.

RME approach to teaching is basically train students to work on formal or informal mathematics from contextual problems using mathematical concepts, operation, and procedures which apply and understood by the students. Rules, formulas, and condition applying in mathematics should be implemented in the right way to get correct answers. Under teacher's help, students show the connection of applied rules, prove the applying mathematical rules, comparing models, make use of different models, combine and apply models, and formulate mathematical concepts and generalize them. With this way students' ability to think critically is developed and trained.

The students' activity in the teaching under RME can take place well, since in the process of the teaching activities are done in groups, between groups, (class discussion) to solve contextual problems using students' activity sheets. In addition, RME trains students to form their knowledge by themselves through a set of problem solving, while LAS are designed to trigger reinvention by students.

The students of the experiment group were better since they were better due to their activities during the teaching process in the experiment. Observation's findings indicated that the percentage of the activity of individual student tended to increase in every teaching until the last meeting in this experiment, some students' activities relating with mathematical critical thinking reached 86.3% (very active category). In the first meeting, the activity of the students in the teaching process was just 72.8%. However, in the second meeting, the percentage tended to increase because the students had adjusted with the teaching approach used. This was shown by students' activity in expressing an idea, asking questions, giving comments, and their seriousness in presenting their work.

In regard to response to RME approach, 80.5% of the students expressed that they were happy with the approach, and this means that they responded positively.

5. CONCLUSION

Mathematical critical thinking ability of students taught under RME approach was at high category of the four aspects improved, algorithm analysis aspect was still low, whereas the aspects of identifying and justifying concept, generalizing and solving problem aspects developed well.

1. Mathematical critical thinking of students taught under conventional approach was at the middle category.
2. Improvement of mathematical critical thinking taught under RME was better than that of students taught under conventional approach.
3. Students' responce to the teaching under MRE was positive, they were happy about the teaching process. In addition, students' participation in activities was good and tended to increase.

6. SUGGESTIONS

1. RME approach is one of many approaches to the teaching of mathematics, and is good to apply for improving mathematical critical thinking ability.
2. Teachers who apply RME approach in their teaching are suggested to pay special attention to algorithm analysis aspect.
3. Mathematics teachers, especially the ones in Southeast Sulawesi, in their efforts to improving thinking ability in the teaching of mathematics are suggested to frequently use constructivism-based approaches.

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