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Development of Learning Devices Based on Realistic Mathematics Education to Improve Students' Critical Thinking Ability at MAN 1 Tanjung Pura

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Abstract
This study aims to: 1) develop the learning devices based on RME that meet the valid, practically, and effective criteria; 2) improvement of critical thinking ability of senior high school students by using learning devices based on RME developed. The type of this research is a development research. The development model used is Four-D Model which consists of 4 stages: define, design, develop, and disseminate. The results of the study show that: 1) the learning devices based on RME developed meet the valid criteria, both in the content validity and construct validity; 2) the learning devices based on RME developed meet the practical criteria, practically in terms of: a) validator assessment about ease of use of learning device, and b) implementation of learning devices. 3) the learning devices based on RME developed meet the effective criteria, effectiveness in terms of: a) students' learning mastery in a classical way; b) achievement of learning objectives; c) learning time; and d) students' positive responses; 3) An increased in students' critical thinking ability by using learning devices based on RME.
Keywords: Development, Learning Devices, Realistic Mathematics Education, Critical Thinking

1. Introduction

Education is one of the main pillars in anticipating the future, because education is always oriented to the preparation of learners to play a role in the future (Tirtarahardja, 2008). The role of education in facing the future is closely related to mathematics learning. Mathematics is one branch of science that is very important especially in its application in everyday life. Mathematics is a means or means to find answers to problems facing humans, ... and most importantly is to think in man himself to see and use his relationships (Hasratuddin, 2015). From that opinion we can say that mathematics is a means of thinking to find solutions from various problems of life.

The importance of mathematics is also evident from the continuous learning of mathematics from elementary to college level. Cockroft (Abdurrahman, 2009) states that mathematics needs to be taught to students because it is always used in all aspects of life. The purpose of learning mathematics in the 21st century is that students are able to have high-level thinking ability. (Mustafa et al., 2017) state "in the study of mathematics, the ability to think and to solve the problem is one of the most important abilities." One of the most important thinking skills possessed by a student is the ability to think critically.

According to Hassoubah (2004) "critical thinking ability is very important because critical thinking ability can support students in decision making, assessment and problem solving". With this ability students can study problems systematically, formulate innovative questions and design original solutions. In line with this according to Johnson (2011) said that "with critical thinking, students can achieve a deep understanding". This understanding will help students solve problems in everyday life and help students make informed decisions. A student is said to have critical thinking ability if in solving problems capable of: (1) analyzing, (2) synthesizing, (3) solving problems, and (4) summing up.

With the importance of critical thinking ability, students should have good critical thinking ability. But based on the results of observations in the field kemampun critical thinking students are still low. From the diagnostic test given to 29 students, only 3 students (10,34%) were able to answer the problem correctly, but not yet able to answer by fulfilling all indicators of critical thinking ability of mathematics. Based on the observations, the main constraint of most students in the process of completion that occurs is at the stage of analyzing and synthesizing. Students have not been able to analyze the problem well, it is difficult to separate the information into smaller and more detailed sections, and it is difficult to incorporate the information into new forms or arrangements so that problem solving is not appropriate.

The findings in the field indicate that the low ability of students critical thinking because the ability is not a major focus in learning activities. This is also because teachers have not been able to prepare appropriate learning devices to improve students' critical thinking ability. Mustafa et al (2017) stated that the low ability of students thinking is caused by the teacher has not been able to arrange the appropriate learning devices to trained students high-level thinking ability. The statement is also supported by Haggarty and Keynes (Muchayat, 2011) that "in order to improve the teaching and learning of mathematics in the classroom, it is necessary to improve the understanding of teachers, students, materials used for learning and interaction between them". In order for the learning objectives to achieve the expected goals, it is necessary to develop learning devices by choosing the right learning approach.

One approach that is considered appropriate is Realistic Mathematics Education. This approach is a learning approach that directs students to real problems, and makes students active especially in building their thinking ability. Gravemeijer (Hasratuddin, 2002) states that there are three principles of PMR that can be used as a reference in developing learning devices, namely: (1) Guided reinvention / progressive mathematizing, (2) Didactical phenomenology, and (3) Self-developed model. Based on the description, learning devices with the application of realistic mathematics education is expected to be an alternative to create a good learning in improving students' critical thinking ability.

2. Literature

2.1. Critical Thinking Ability

Thinking is manipulating or managing and transforming information in memory (Santrock, 2007). Thinking is done to form concepts, reasoning and thinking critically, making decisions, thinking creatively and solving problems. According Sagala (2010) that "thinking is a dynamic process by taking three steps: the formation of understanding, the formation of opinions and decision-making". Through these three steps a person takes the stage of thinking before finally taking a decision in various ways.

Chaffee (Abidin, 2016) states that critical thinking is an active and purposeful thinking activity. Critical thinking is an organized effort to understand the world cautiously through the activities of weighing our thoughts and the thoughts of others to clarify and enhance our understanding of everything. Similarly, Butterworth and Thwaites (Abidin, 2016) state that "critical thinking is always characterized by three basic activities of analysis, evaluation, and argument". Analysis means identifying the key words of an information and reconstructing the information in order to capture the full meaning and fulfill the adequacy aspect. Evaluation means assessing the power of information on the basis of good or poor arguments in favor of conclusions in the information or how strong evidence is presented on the claims submitted. Argument means an explanation or response given by a critic over the information it obtains. Critical thinking can also be said to be a decision-making skill based on good and right reasons. This skill is obtained through a series of processes of effectively reflecting, analyzing, and evaluating various issues or problems encountered in life. Through this process will be known the reasons which can then be said as the premise and obtained beliefs supported by the reason which is hereinafter referred to as a conclusion.

Dewey (Fisher, 2009) defines critical thinking as "active, persistent, and conscientious consideration of a belief or form of knowledge that is taken for granted in terms of the reasons that support it. According to Ennis (1996) there are six basic elements in critical thinking, namely: focus, reason, inference, situation, clarity and overview. Based on the expert's opinion, in this research, the ability to think critically of the ability of a reasonable and reflective thinking to take a conclusion that is believed to be true and believed to be true that contains the indicators (1) analysis, (2) synthesize, (3) recognize and solve problems , and (4) concluded.

2.2. Realistic Mathematics Education (*RME*)

RME is rooted in 'mathematics as a human activity,' and the underlying principles are guided reinvention, didactical phenomenology, and emergent models. These principles are based on Freudenthal's philosophy which emphasizes reinvention through progressive mathematization (Fredenthal, 1991). In RME, context problems are the basis for progressive mathematization, and through mathematizing, the students develop informal context-specific solution strategies from experientially realistic situations (Gravemeijer & Doorman, 1999). Thus, it is necessary for the researchers who adapt the instructional design perspective of RME to utilize contextual problems that allow for a wide variety of solution procedures, preferably those which considered together already indicate a possible learning route through a process of progressive mathematization.

The *realistic* mathematics education approach is based on a different point of view of mathematics education. The main difference with the mechanistic and structural approaches is that RME does not start from abstract principles or rules with the aim to learn to apply these in concrete situations (Wubbels et al., 1997). On the contrary, much importance is attributed to informal strategies and constructions that pupils develop themselves. They form the most natural way for pupils to attack problems and RME makes use of this in the instructional design of lessons. Thus, in lesson work pupils are encouraged to realize and identify mathematical aspects in their daily life and to give meaning to problems from a real world context.

According to Gravemeijer (1994) there are four stages of model development in realistic mathematical approaches, namely: real, reference, general, and formal situations. Gravemeijer (1994) also formulated five characteristics in RME, namely: 1) phenomenological exploration, 2) bridging by vertical instruments, 3) student contribution, 4) interactivity, and 5) intertwining.

On the other hand, De Lange (1995) mentions "there are five basic characteristics in doing RME-based learning, yesotu: 1) The use of real-life contexts, 2) The use of use models, 3) Student's free production; 4) Interaction, 5) Intertwining ". In this study the RME approach is a learning process that starts from the real things for students and the environment and emphasizes the skills of 'process of doing mathematics'. The steps of the RME approach in this study are: 1) conveying contextual issues, 2) explaining contextual issues, 3) resolving contextual problems 4) comparing and discussing answers, and 5) concluding.

2.3. Quality of Learning Devices

Akker (1999) states in the study of the development of learning models need quality criteria that is validity, practically, and effectiveness. This is also in line with Rochmad (2012) 's opinion that "to determine the quality of the outcomes of the development of models and learning devices it is generally necessary to have three criteria: validity, practicality and effectiveness". Therefore in this study the quality criteria of the developed device are reviewed based on validity, practicality, and effectiveness.

Akker (1999) states "validity refers to the extent that the design of the intervention is based on state-of-the art knowledge (content validity) and that the various components of the intervention are consistently linked to each other (contruct validity)" . The components of the indicators of the validation aspects of the validation criteria in general are: format, language, illustrations, material content and learning objectives (Akker, 1999).

According to Akker (1999) practically refers to the extent that the user (or other experts) consider the intervention as appealing and usable in normal conditions. While Nieveen (2007) states practicality is reviewed by "Expected: The intervention is expected to be usable in the settings for which it has been designed and developed. Actual: The intervention is usable in the settings for which it has been designed and developed ". Therefore the practicality in this research is reviewed based on: 1) validator assessment about ease of use of learning device, and 2) practicality of instructional device.

Herman (2012) states that the effective criteria of a learning if it meets 3 of the 4 criteria of effectiveness, namely the achievement of learning achievement, student activity, positive student response and the ability of teachers to manage learning. Hasratuddin (2015) mentions the criteria of effectiveness include the achievement of classical learning completeness, achievement of learning objectives, time spent in learning, and student responses to learning. Based on some expert opinions, the effective criteria in this study focuses on: (1) mastery of student learning outcomes classically, (2) achievement of learning objectives, (3) learning time, and (4) positive student response.

3. Methods

This type of this research is Development Research. The development model used is a Four-D development model consisting of 4 development stages: define, design, develop, and disseminate (Thiagarajan et al, 1974).

3.1. Subjects and Research Objects

Subjects in this study were students of class X IPA-2 and X IPA-1 in MAN 1 Tanjung Pura, each consisting of 41 students and 40 students. While the object in this study is a learning device of mathematics class X based on RME developed on the material 'system of linear equations three variables'.

3.2. Learning Device Development

Learning devices that were developed in this research were Learning Implementation Plan (RPP), Teacher Handbook (BPG), Student Book (BS), Student Activity Sheet (LAS) and Research Instrument in the form of Critical Thinking Test (TKBK). Learning device development is done by applying 4-D development model (Thiagarajan et al, 1974) with four development stages: define, design, develop, and disseminate. The design of device development in this study can be seen in Figure 1 below:

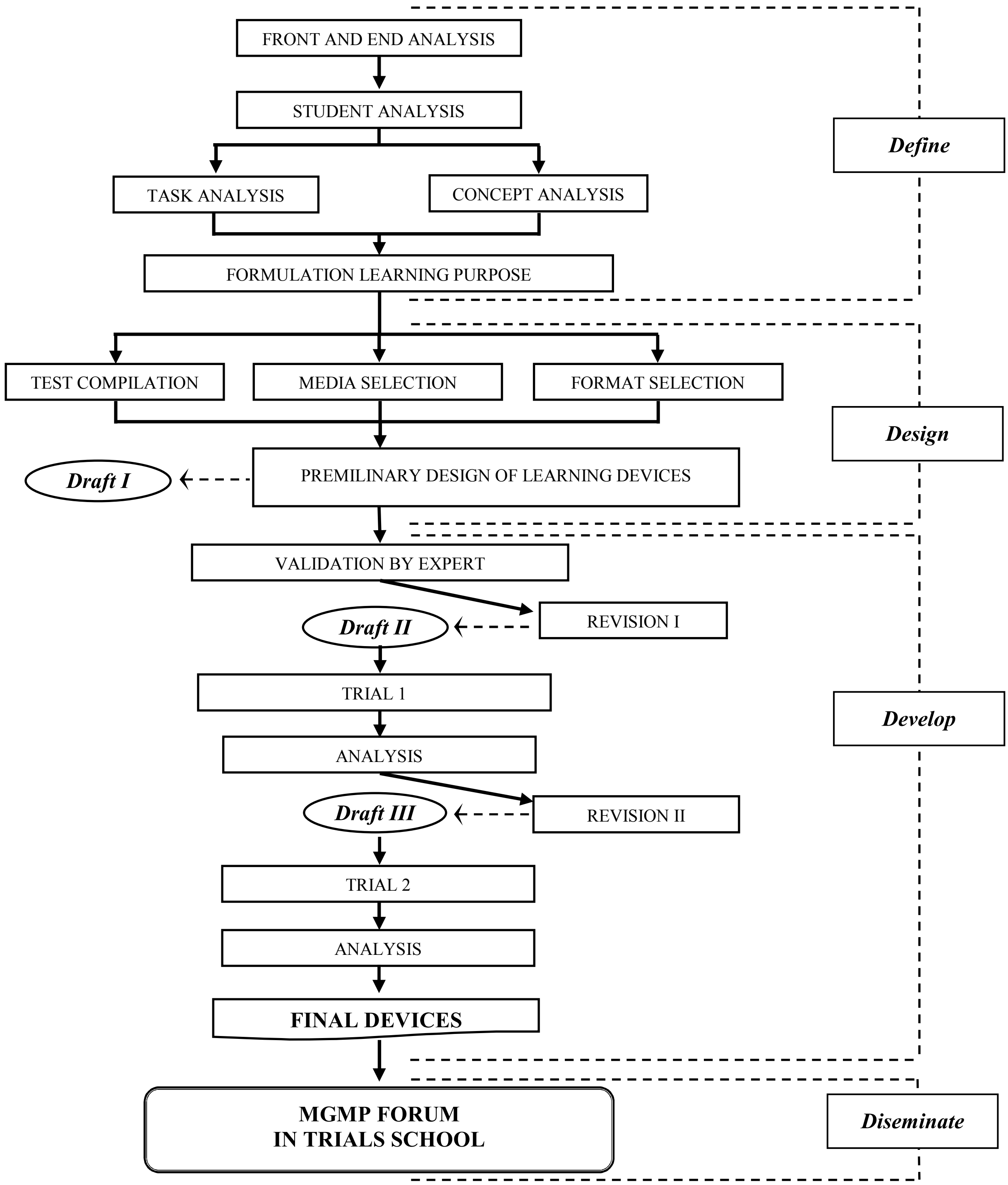

Figure 1. Chart Development of Learning Devices with 4-D Model

3.3. Instruments and Data Analysis Technique

The instruments used in this study include instruments for assessing the quality of learning devices covering aspects of prevalence, practicality and effectiveness. Instruments used in the form of observation sheets, questionnaires, and tests. For more details can be seen in Table 1 below:

Table 1. Research Instruments

Aspect	Instruments	The Observed Data	Respondent
The Validity of Learning Devices	Validation Sheet	Validity of RPP, LAS, BS, BPG, TKBK	Expert/Practitioners
The Practicality of Learning Devices	Validation Sheet	Practically of RPP, LAS, BS, BPG, Critical Thinking Skill Test	Expert/Practitioners
	Observation Sheet	Learning Devices Implementation	Observer
The Effectiveness of Learning Devices	Test	Metacognition Skill Test	Research Subject
	Observation Sheet	Students Activity	Observer
	Questionnaire	Student Response	Research Subject

Learning devices are said to be valid if the average validator's assessment of all learning devices is at minimum valid criteria with an average value of ≥ 4 (Mustafa, 2017). If not met, it is necessary to revise and revise activities. And so on until obtained learning devices that meet the validity of the contents. Furthermore, the validity of the constructs to test the ability to think critically. Before being used for field trials, the critical test items were tested outside the research subject to measure validity and reliability. To measure the validity of item can use product moment correlation formula and to calculate the reliability coefficient of test items used Alpha-Cronbach formula (Arikunto 2012).

Furthermore, learning device implementation is in the form of RPP, LAS, BPG and BS. The Implementation of learning device criteria are met if the percentage minimum average total score is ≥ 80% (Mustafa et al, 2017).

The effectiveness of learning devices is reviewed based on: 1) Student learning achievement is classically met if ≥ 85% gets test score ≥ 65; 2) Achievement of learning objectives is met if the score of each Basic Competency reaches 75% of maximum score; 3) Learning time is fulfilled does not exceed the usual learning time (Hasratuddin, 2015), and 4) student responses are met if the classical ≥ 80% of subjects provide a positive response (Mustafa, 2017).

After learning device obtain the valid and effective criteria, it is then reviewed the improvement of students' mathematical critical thinking ability based on: 1) increase of classical average value based on TKBK result from trial I to trial II; and 2) increasing the average value of each indicator based on the results of TKBK from trial I to trial II.

4. Result

The following is the result of the study obtained based on experimental learning device in MAN 1 Tanjung Pura with two trials. The results of the tests described included: 1) validity of learning device, 2) practically of learning devices, 3) effectiveness of learning devices, and 4) improvement of students' mathematical critical thinking ability.

4.1. Validity ofLearning Device

Based on the validator assessment consisting of 3 experts and 2 practitioners, it is obtained that the learning devices developed meet the criteria as listed in Table 2 below:

Table 2. The Result of Content Validation of Learning Devices

No	Learning Devices	Average Value of Total Validity	Validation Level
1	Learning Implementation Plan (RPP)	4,38	Valid
2	Student Activity Sheet (LAS)	4,38	
3	Teacher Handbook (BPG)	4,41	
4	Student Book (BS)	4,41	
5	Critical Thinking Ability Test (TKBK)	-	All Items Valid

Based on Table 2, it is found that all learning devices meet the valid criteria because they get the overall average score ≥ 4. Then the result of the instrument test shows that all the items of critical thinking ability test meet the valid criteria and get the reliability value that is r_{11} = 0,825 (very high category). Because the learning devices based on Realistic Mathematics Education developed to meet the criteria of content validity and constructed validity of the constructs.

4.2. Practicality and Effectiveness of Learning Devices

4.2.1. Description of the Practicality and Effectiveness of Learning Devices in Trial I

The practicality criteria of learning devices based on the validator assessment are met, because all validators assess the developed learning devices can be used easily. Implementation of learning devices is met, in terms of the average of all learning meetings obtained a percentage of 81.46% ≥ 80% (good category). Based on these descriptions, the learning devices developed meet the practical criteria.

Based on the results of the test I obtained the completeness of student learning outcomes in classical as listed in Table 3 below:

Table 3. Posttest Results of Students' Critical Thinking Abilities In Trial I

No	Score Interval	Sum of Students	Persentage	Category
1	0 $\leq$ SKBK < 54	6	14,63 %	Very low
2	54 $\leq$ SKBK < 65	10	24,39 %	Low
3	65 $\leq$ SKBK < 79	14	34,14 %	Medium
4	79 $\leq$ SKBK < 89	8	19,51 %	High
5	89 $\leq$ SKBK $\leq$ 100	3	7,32 %	Very High

Explanation:

SKBK : score of students' critical thinking ability

From Table 3, it can be seen that the total number of subjects who got the score ≥ 65 reached 25 students (60,97%) from 41 students, so it has not fulfilled the completion criteria of the classical learning result set.

Furthermore, the achievement of learning objectives in trial I can be seen in Table 4 The following:

Table 4. Achievement of Learning Objectives in Trial I

Basic Competence of Materials	% Achieved	Criteria
Compile and discover the SPLTV concept.	75,30%	Achieved
Resolving contextual issues related to SPLTV	68,60%	Not Achieved

From Table 4, it is seen that only the first Basic Competency is able to achieve 75% achievement percentage. Thus the achievement of learning objectives on trial I based on posttest result of students' mathematical critical thinking ability has not been achieved.

The achievement of learning time in trial I was 4 x 45 minutes (2 x meetings). Compared to the usual learning done so far, there is no difference between achieving time of learning based RME and achieving regular learning time. This is in accordance with the predetermined learning time criteria, so the achievement of time trial I have been met.

Based on the results of the experiment also obtained the average percentage of total positive responses of students to the device and learning activities on trial I amounted to 86.59%. Therefore, students' responses are also fulfilled because students who respond positively to the components and learning implementation achieve ≥ 80%.

Based on the above results obtained that the learning device only meets the aspects of learning time and the positive response of students specified, but has not fulfilled the completeness criteria of classical learning outcomes and achievement of learning objectives set. Thus the learning device developed has not met the effective criteria. Therefore a revision of the learning device must be revised and re-tested to produce an effective learning devices.

4.2.2. Description of the Practicality and Effectiveness of Learning Devices on Trial II

Based on the results of the second experiment, the students' learning achievement in classical as shown in Table 5 is as follows:

Table 5. Posttest Results of Students' Critical Thinking Abilities in Trial II

No	Score Interval	Sum of Students	Persentage	Category
1	0 $\leq$ SKBK < 54	2	5,00 %	Very low
2	54 $\leq$ SKBK < 65	3	7,50 %	Low
3	65 $\leq$ SKBK < 79	15	37,50 %	Medium
4	79 $\leq$ SKBK < 89	12	30,00 %	High
5	89 $\leq$ SKBK $\leq$ 100	8	20,00%	Very High

Explanation:

SKBK: score of students' critical thinking ability

From Table 5, it can be seen that the total number of completed subjects received ≥ 65 reach 35 students (87,50%) from 40 students, so that fulfill the completion criteria of classical learning result which is determined.

Furthermore, the achievement of learning objectives in trial II can be seen in Table 6 below:

Table 6. Achievement of Learning Objectives in Trial II

Basic Competence of Materials	% Achieved	Criteria
Compile and discover the SPLTV concept.	87,88%	Achieved
Resolving contextual issues related to SPLTV	75,16%	Achieved

From Table 6 it is seen that the whole Basic Competence o the material reaches the percentage of 75% attainment. Thus the achievement of the learning objectives in the second trial based on posttest result of students' mathematical critical thinking ability has been achieved.

The achievement of learning time in trial I was 4 x 45 minutes (2 x meetings). Compared to the usual learning done so far, there is no difference between achieving RME-based learning time and achieving regular learning time. This is in accordance with the predetermined learning time criteria, so the achievement of time trial II has been met.

Based on the results of the experiment also obtained the average percentage of total positive responses of students to the devices and learning activities on trial II of 98.75%. Therefore, students' responses are also fulfilled because students who respond positively to the components and learning implementation achieve ≥ 80%.

Based on the above results obtained that the learning device meets all the specified effectiveness criteria, namely the completeness of learning outcomes in the classical, the achievement of learning objectives, learning time and positive response of students. Thus the learning device developed has met the effective criteria.

4.3. Description of Improving Student's Critical Thinking Ability

Based on the posttest result of students' critical thinking ability, the average score on trial I was 72,00 and II trial was 81,00. Thus there is an increase in the average value of students' critical thinking ability of mathematics between trials of 9.00 or 12.5%. Then the improvement of critical thinking ability in each indicator can be seen in Table 7 below:

Table 7. Improvement of Critical Thinking Ability on Each Indicator

Indicator of Critical Thinking Skill	Mean			
	Trial I	Trial II	Increase	%
Analyze	76,75	88,25	11,5	14,98%
Synthesis	73,25	85,25	12,0	16,38%
Solving Problem	69,50	78,00	8,5	12,23%
Concluded	67,25	72,75	5,5	8,18%

The results show that students' mathematical critical thinking ability using Learning devices based on RME developed improved from trial I to trial II. So it is concluded that the learning devices based on RME developed to improve students' critical thinking ability mathematically.

5. Discussion

The results showed that the learning devices based on RME developed fulfilled the valid criteria, practical and effective criteria. The validity of learning devices should be reviewed based on the content validity and construct validity (Akker, 1999). In this research both aspects of validity have been fulfilled. The validity of the content through validator assessment, and the validity of the construct through the test instrument test outside the subject of research. The content validity of a test questioned how far a test measures the level of mastery of the content of a certain material that should be mastered with the purpose of teaching, while the construct validity as how exactly the test is capable of measuring the concept that should be measured (Asmin and Mansyur, 2014).

Learning devices are said to have good quality must meet the practical and effective criteria (Nieveen, 2007). Practicality in terms of how far developed devices easy to use. This is important because the ease of use of the device will have an impact on the ease in developing students' creative thinking ability. While effective in question is the extent to which developed learning devices are able to achieve the predefined goal criteria. In this study the learning devices that have been developed meet the effective criteria based on the achievement: 1) mastery of classical learning outcomes, 2) achievement of learning objectives, 3) learning time, and 4) student responses. The effectiveness of learning devices is fulfilled through two series of trials, between the two experiments carried out the revision process of learning devices. The revision is done because in the first experiment the learning device has not fulfilled all the specified effective criteria. Whereas after the process of revision of learning devices, all the established effective criteria are met (Yuliani and Saragih, 2015; Aufa et al, 2016; Mustafa et al, 2017).

The learning devices based on RME developed are also able to improve students' critical thinking ability. The improvement of students' critical thinking ability is due to the improvement of the quality of the device and the learning process. As Haggarty and Keynes (Muchayat, 2011) stated that "in order to improve the teaching and learning of mathematics in the classroom it is necessary to improve the understanding of teachers, students, materials used for learning and interaction between them".

On the other hand, the role of the RME approach in learning also influences the improvement of students' critical thinking ability. With the implementation of RME during the learning process also involves students in their own inquiry, enabling them to interpret and explain real-world phenomena and develop an understanding of the phenomenon independently. This is in line with Piaget's constructivism theory (Sugiyono, 2012) that "the importance of learners' activities to actively build their own knowledge, such as the activities of learners in processing materials, working on problems, making conclusions, and formulating a formula with its own words which is the activity which is necessary for learners to build their knowledge ". Thus the Learning devices based on RME developed is appropriate to cultivate and improve students' critical thinking ability.

6. Conclusion

Based on the results and discussion in this study, presented several conclusions as follows:

1) The learning devices based on RME developed to improve students' critical thinking ability of mathematics meet the valid criteria. Validity is reviewed based on content validity and construct validity.
2) The learning devices based on RME developed to improve students' mathematical critical thinking ability meet the practical criteria. Practicality is reviewed based on: a) validator assessments related to ease of use of learning devices, and b) the implementation of learning devices.
3) The learning devices based on RME developed to improve students' mathematical critical thinking ability meet the effective criteria. Effectiveness is reviewed based on: a) mastery of student learning outcomes in a classical manner, b) achievement of learning objectives, c) learning time, and d) positive student responses.
4) Critical thinking ability of students' by using the learning devices based on RME developed were increased. Improvements were reviewed based on: a) classical average based on TKBK result from trial I to trial II and b) classical average of each indicator based on TKBK result from trial I to trial II.

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