Journal of Mathematical Sciences and Applications, 2019, Vol. 7, No. 1, 1-9
Available online at http://pubs.sciepub.com/jmsa/7/1/1
Published by Science and Education Publishing
DOI:10.12691/jmsa-7-1-1

Development of Learning Device through Problem Based Learning Model Assisted by Geogebra to Improve Students' Critical Mathematical Thinking Ability

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Received September 09, 2019; Revised October 18, 2019; Accepted November 12, 2019

Abstract This study research was aimed at finding the validity, practicality and effectiveness of Problem based learning model assisted by Geogebra and describing the improvement of students' mathematical critical thinking skills. The learning devices developed are the Lesson Implementation Plan, teacher's book, student's book, Student Worksheet and student's mathematical critical thinking ability test instrument. This research is a Research and Development, using the Thiagarajan, Semmel and Semmel development models, the 4-D model. Learning devices had fulfilled the valid criteria's according to experts, and tested in class XI at MAN Labuhanbatu. The results of research had shown that the learning device of problem based learning model assisted by Geogebra had fulfilled the practical criteria's and effective and could improve students' mathematical critical thinking skills.

Keywords: *development of learning device, problem based learning model assisted by Geogebra, students' mathematical critical thinking skills*

Cite This Article: Nurmanita, Pargaulan Siagian, and Pardomuan Sitompul, "Development of Learning Device through Problem Based Learning Model Assisted by Geogebra to Improve Students' Critical Mathematical Thinking Ability." *Journal of Mathematical Sciences and Applications*, vol. 7, no. 1 (2019): 1-9. doi: 10.12691/jmsa-7-1-1.

1. Introduction

Education holding on plays an important role in preparing quality of human resources which became the driving force for the advancement and prosperity of the Indonesian people later. Ministry of Education (Permendiknas) No. 22 of 2006 concerning Standards for Elementary and Secondary Education Units stated that mathematics is a universal science that underlies the development of modern technology which has an important role in various disciplines and advancing human thinking [1]. Therefore, in the education curriculum in Indonesia placed on mathematics as a compulsory subject given to students from elementary to high school and even in tertiary institutions with a greater proportion of time allocation than in other fields of study. Mathematics needs to be taught to students because: (1) it is always used in all aspects of life, (2) all fields of study require appropriate mathematical skills, (3) a means of communication that is strong, concise, and clear, (4) can be used to present information and in various ways, (5) increase the ability to think logically, thoroughness, and spatial awareness, and (6) provide satisfaction with efforts to solve challenging problems [2].

Teachers as the spearhead of education in the field are required to be able to develop in various models of learning made from computer media teaching so that learning is able to keep up with the times and make students more interested in learning the material delivered by the teacher. The success of a teacher in learning is expected to fill these objectives requires a careful preparation. Before the teacher teaches, the teacher is expected to prepare the material to be taught, prepare learning media to be used, prepare questions and directives to lure students to actively learn, learn about students' conditions, understand student weaknesses and strengths, and learn student's initial knowledge, all of which will be decomposed in their implementation in the learning device. Therefore, the device used also determines the quality of learning [3].

Everything is could be enable teachers and students to carry out the learning process according to the curriculum have called a learning device [4]. Learning devices has included learning implementation plans, teacher books, student books, student worksheets and tests to measure students' mathematical critical thinking skills. Ministry of Education (Permendikbud) No. 22 of 2016 concerning Basic and Secondary Education Process Standards that the learning process in educational units is held interactively,

inspiring, fun, challenging, motivates students to participate actively, and provides sufficient space for initiative, creativity, and independence in accordance with talent, interests, and physical and psychological development of students [5]. For this reason, each education unit conducts a learning plan, implements the learning process and evaluates the learning process to improve the efficiency and effectiveness of the achievement of graduate competencies.

The means of intended learning device can be a learning device developed by the teacher itself. Learning device compiled by the teacher themselves are more effective because they are arranged based on the nature and characteristics of the students. The Lesson Implementation Plan made by mathematics teachers at MAN Labuhanbatu has not used ICT-assisted learning models and media to activate students. The teacher only uses blackboard media in mathematics learning, the learning model used is also still in routine activities for all materials such as lectures and assignments.

The teacher has not designed his own student book and the teacher's book in learning mathematics. Student books and teacher books used in learning mathematics at MAN Labuhanbatu are books provided by the government in the implementation of the 2013 Curriculum. These books are intended for schools in various national directions. The contents of the book are made generally for the condition of students in Indonesia this has resulted in the contents of the book not being able to reach the needs and specific characteristics of each school.

Besides the learning process carried out by teachers in the classroom tends to achieve the target material or according to the contents of the book material used as mandatory books with orientation to routine questions, the teacher has not designed and used students' worksheets in the process of learning mathematics in class XI and learning achievement tests are only taken from the teacher's handbook. Mathematics teachers should be expected to be able to arrange the worksheet of students who has support the learning process in order to help students develop their mathematical critical thinking skills.

Based on the explanation above, the developed learning device is not fully designed by the mathematics teacher himself, so it often is not in accordance with the characteristics of students as targets. This causes students to not be able to achieve their learning goals, students become passive in learning.

Mathematics learning in the 2013 curriculum has the aim to achieve High Order Thinking Skills (HOTS) early on. Critical thinking is one manifestation of HOTS. Critical thinking is a process of using the ability to think rationally and reflectively which aims to make decisions about what is believed or done [6]. Mathematical critical thinking skills are very important for students because with these skills students are able to be rational and choose the best alternative choices for themselves [7]. Without the ability to think critically, one cannot be a competitor to others and is always left behind. The ability to think critically is an important component that students must have, especially in the process of learning mathematics. This is so that students are able to create or formulate, identify, interpret and plan problem solving.

However, based on observations obtained at the research site, the reality on the ground shows that students' mathematical critical thinking skills are still low. Based on the results of the interview of the author on one of the mathematics teachers of class XI at MAN Labuhanbatu obtained information that the problem faced by the teacher is the lack of students' ability to understand mathematical questions in the form of contextual and open-ended problems and difficulties in solving problems presented in accordance with concepts that have been taught, the cause of this is in learning mathematics students tend to memorize formulas, imitate examples of questions given by the teacher, and the lack of students in understanding the material so that each time given a different mathematical problem, students have not been able to work on the problem proficiency level. Lack of understanding of students learning mathematics has an impact on student learning outcomes obtained less satisfactory.

The low ability of students 'mathematical critical thinking is also seen when researchers conduct research and initial observations in class XI at MAN Labuhanbatu, the facts in the field show that students' mathematical critical thinking abilities are still not in accordance with the expected indicator achievement. Students still find it difficult to understand and solve problems designed to look at students' mathematical critical thinking skills. Most students forget the basic concept of the material, this is seen when given a question related to the content, students are not able to solve it and ask the teacher which formula to use. This shows that students do not master the concepts. This happens because learning that has occurred so far does not involve students, this causes students to be passive in learning. Mathematics is considered as a subject that is difficult to understand, so it is less desirable by some students. Difficult students understand mathematics because mathematics they feel is less meaningful [8].

The low ability of students' mathematical critical thinking is caused by many factors, one of which is in the learning of mathematics there are still many mathematics teachers who embrace the paradigm of the transfer of knowledge. Interaction in learning occurs only in one direction, namely from the teacher as a source of information and students as recipients of information. Students are not given many opportunities to actively participate in teaching and learning activities in class, in other words learning is more centered on the teacher, not on students. The learning process that occurs in one direction, and is boring for students, this caused in a low mathematical critical thinking ability of students.

To improve students' mathematical critical thinking skills which ultimately results in increased student mathematics learning outcomes, it is necessary to improve learning. The selection of the right learning model is an important part for teachers before giving lessons in class [9]. Development of learning devices must be based on appropriate learning models. The use of learning models that are not in accordance with student development will have an impact on the stages of student development in learning. Development of learning devices must be arranged based on the right learning model as well. The use of learning models that are not in accordance with the

development of students will have an impact on the development stage of student learning [10].

One of the predicted learning models that can be used to improve the quality of the process and learning outcomes is the Problem Based Learning model. Problem Based Learning (PBL) is a learning model that exposes students to a problem so that students can develop higher-order thinking skills and problem solving skills and acquire new knowledge related to these problems [11]. Problem based learning model is appropriate with the condition of students with daily life and 2013 Curriculum that is currently in effect [12].

Problem based learning was chosen because (1) it provides problems that are close to real life and might occur in real life, (2) encourages students to engage in learning activities, (3) encourages the use of various approaches, (4) gives students the opportunity to make choices about how and what he will learn, (5) encourage collaborative learning, and (6) help achieve quality education [13].

Responding the problems are arise in mathematics education in addition to developing learning device with the Problem Based Learning model, it is also necessary to find learning media that can improve students' mathematical critical thinking abilities. Technology has a very important role in learning mathematics [14]. Information technology is an instrument that changes the learning paradigm from teacher-centered to student-centered, the teacher who initially as a source of information and channel of knowledge turns into a facilitator in learning, and changes the role of students who initially only as recipients of information and passively become students who are actively involved in her own learning [15]. A learning model will certainly be more innovative if applying media in the implementation process [16]. So that students are more interested in solving problems given by the teacher in the problem based learning model, the teacher uses the media [17].

One of the software (applications) that can be used as a medium for learning mathematics is Geogebra [18]. Geogebra was developed by Markus Hohenwater in 2001. Geogebra is a computer program (software) to teach mathematics, especially geometry and algebra [19]. Geogebra software can help teachers to convey abstract mathematical material that is easier to understand. In addition this software is made to train the creativity and critical power of students [20]. In addition, learning by using Geogebra puts students as the subject of learning, students not only act as recipients of subject matter through verbal teacher explanations but also they have a role to find their own core of the subject matter. With the Geogebra assistance of software in the Problem Based Learning model, mathematical concepts that were initially complex can be visualized precisely and easily to be understood.

To overcome in this case the researchers tried to develop a learning device throught problem based learning model assisted by Geogebra, to improve students' mathematical critical thinking skills. Based on the above problems, it is felt necessary to make efforts **"Development of Learning Device Through Problem Based Learning Model Assisted by Geogebra to Improve Students' Critical Mathematical Thinking Ability"**

2. Review of Literature

2.1. Students' Mathematical Critical Thinking Abilities

Critical thinking is a process of using the ability to think rationally and reflectively which aims to make decisions about what is believed or done [6]. Students who think critically are students who are able to identify problems, evaluate and construct arguments and are able to solve these problems correctly [21]. Critical thinking includes the ability to analyze, draw conclusions, make interpretations, explanations, self-regulation, curious, systematic, wise looking for the truth, and confidence in the thought process that is done is needed by someone in an effort to solve a problem [22]. A student can be said to think critically if the student is able to test his experience, evaluate knowledge, ideas, and consider arguments before getting justification. In order for students to become critical thinkers, attitudes must be developed to reason, be challenged, and seek truth [23].

Based on the opinions of the experts above, it can be concluded that the ability of students to think critically mathematically is an ability to think students effectively to conceptualize, apply, analyze, synthesize, and evaluate information obtained from observation, experience, reflection, reasoning, or communication with the aim of making decisions which makes sense about what is believed in the given mathematical problem.

2.2. Problem Based Learning Assisted by Geogebra

Problem Based Learning is designed in the form of learning that begins with the structure of real problems related to mathematical concepts to be taught, students not only receive information from the teacher but Problem Based Learning is not designed to help teachers provide as much information to students as possible but to help students develop their intellectual abilities, thinking abilities, and problem solving that students encounter in daily life. When using the PBL, teachers help students to focus on solving problems in the context of real life, encouraging them to consider the situation in which there is a problem and try to find a solution [24]. In order to achieve this goal, it is best to apply the Problem Based Learning model using media or software. One computer program (software) that can be utilized in learning mathematics, especially geometry is Geogebra. This sweetened software can be used as a aid device of learning for mathematics including mathematical material such as arithmetic, geometry, algebra and calculus [18].

The Syntax of problem based learning model contains five main steps that teachers begin by introducing students to problems that end with the presentation and analysis of student work. The five stages are presented in the following table [25]:

Table 1. Syntax of Problem Based Learning Model

Stage	Teacher's Behavior
Stage-1 Student orientation to problems	Explain the learning objectives explain the logistics needed, motivate students to engage in problem solving activities, and submit problems.
Stage-2 Organizing students for learning	Divide students into groups, helping students define and organize learning tasks related to problems.
Stage-3 Guiding individual / group experiences	Encourage students to gather experimental and inquiry information to get explanations and problem solving.
Stage-4 Develop and present the work	Help students plan and prepare reports, documents or models and help them share assignments with their peers.
5th stage Analyze and evaluate the problem solving process	Helping students to reflect or evaluate their investigation and the process they use.

The steps in applying the problem based learning model assisted by Geogebra are as follows: (1). Orientation of students to the problem. The teacher gives the problem listed in the teaching material then students observe it individually or in groups. (2) Organizing students to learn. At this stage students discuss about the problem being faced. Students and teachers design mathematical models related to the problem as an alternative solution to the problem being faced and prove the accuracy of the results with the Geogebra assistance of software. (3) Guiding investigations individually or in groups. Each group will get a Student Worksheet that contains the problem to look for a solution then check the results again with the Geogebra assistance. If students experience difficulties, the teacher provides scaffolding as assistance. (4) Present the work of the group name written on a piece of paper and then shaken to determine which group representative will present the results of the discussion, while the other groups pay attention and respond. (5) The teacher reviews and evaluates the results of students' discussions by determining appropriate problem solving [26].

2.3. Learning Device

Learning device is all things that can allow teachers and students to do the learning process according to the curriculum [4]. Learning device is also a set of learning resources that allow teachers and students to learn. In this study the developed learning device are lesson implementation plans, teacher books, student books, student worksheets and tests of students' mathematical critical thinking skills with problem based learning model assisted by Geogebra on Transformation material in class XI.

3. Method

This type of research is Research and Development. The development of learning device that will be carried out in this study is based on the Thiagarajan development model [7], also known as the "Four-D Model" or 4-D model which includes four stages of development are namely Define, Design, Develop and Desseminate.

This research was conducted at MAN Labuhanbatu in odd semester 2019/2020 Academic Year. The subjects in this study were students of class XI at MAN Labuhanbatu Academic Year 2019/2020, while the object in this study was a learning device through problem based learning model assisted by Geogebra in the form of Lesson implementation plans, teacher books, student books, work sheets of students, and tests of critical thinking skills mathematical students on the Transformation material.

This learning device is said to be worthy of reference to [28] which states that a quality learning product must meet valid, practical and effective criteria. Learning devices are said to be valid if they are in a valid category $\left(4 \le V_{\infty} < 5\right)$or very valid($V_{\infty} = 5$). ractical learning device if: (1) the validator states that learning device are well developed and can be used with little or no revision; (2) the teacher says that the learning device developed are easy to use; (3) students say that the learning deviced eveloped are easy to use; (4) the implementation of the problem-based learning model assisted by Geogebra developed at least in the good category Effective learning device if: (1) the achievement of classical student mastery learning if 85% of students who take the mathematical critical thinking ability test have scored ≥ 75; (2) completeness of learning objectives (minimum of 75% of the learning objectives formulated can be achieved by a minimum of 65% students); (3) the time spent in learning is efficient or does not exceed ordinary learning; (4) students' responses to learning are positive.

To analyze the improvement of students' mathematical critical thinking skills after using problem based learning model assisted by Geogebra, determined by the N-gain formula, namely:

$$N\ Gain = \frac{Skor\ Posttest - Skor\ \Pr etest}{Skor\ Ideal - Skor\ \Pr etest}$$

With the following criteria:

Table 2. N-Gain Category

N-Gain	Category
$N - gain < 0,3$	Low
$0,3 \le N - gain \le 0,7$	Medium
$N - gain > 0,7$	Height

4. Result and Discussion

4.1. The Description of Learning Device Development Stage

In this research development, the learning device of Problem Based Learning model under Geogebra-assistance had fulfilled the effective criteria after the second trial which produced the final draft. The results of the development of the 4-D model learning device are explained as follows:

4.1.1. Define

Based on the results of observations on learning device at MAN Labuhanbatu has founded several weaknesses in the learning device used by teachers which indirectly contribute to the low ability of students' mathematical critical thinking. Learning device used by teachers and

students, produce a teacher-centered learning so that students are not active in learning. Learning implementation plans made by mathematics teachers have not used ICT-assisted learning models and media to enable students. It is seen that teachers only use the white board media in mathematics learning, the learning model used is also still in routine activities for all materials such as lectures and assignments. Learning implementation plans are also not conditioned to the needs or characteristics of students. Furthermore, students 'books which are used in mathematics learning are not designed by the teacher so that they cannot reach students' specific needs and characteristics. In addition, student worksheets have not been utilized at MAN Labuhanbatu, thus causing students to be poorly trained in honing their mathematical abilities. Likewise it also causing with evaluation device. The teacher designs an evaluation device without regard to the ability indicators to be achieved. Besides the test instruments used are still in the form of objective tests, so they do not train students in solving problems. This is the reason that students' mathematical critical thinking abilities are still low.

4.1.2. Design

At this stage an initial draft of a learning implementation plan is produced for 4 meetings, teacher's books, student books and student worksheets for each meeting, a student's mathematical critical thinking ability test, scoring guidelines, and alternative solutions. All results at this design stage are called draft-1. The whole device is designed to be adapted to the problem based learning model assisted by Geogebra to become a unity and its application is expected to have an impact on increasing the mathematical critical thinking ability of MAN Labuhanbatu students.

4.1.3. Develop

After the learning device using the problem based learning model assisted by Geogebra are designed in draft I, a validity test is carried out on the expert / expert and field trials. The aim is to correct errors and weaknesses of the draft results (draft I) which are then used as a basis for revising and refining the learning device. Based on the sheet validated by the validator, it was found that all learning device developed had fulfilled the valid criteria, with a total average value of lesson implementation plan validation is 4.42, teacher's books is 4.39, student books is 4.41 and student's worksheet of 4.38. The students' mathematical critical thinking ability test which has been revised from an expert validator was then trialled to students of class XII at MAN Labuhanbatu. All items of students' mathematical critical thinking ability test items are declared valid and reliable. After calculation, the reliability test of mathematical critical thinking ability is 0.823 (very high category).

After the learning device developed meets the validity criteria (draft II), then the learning device in the form of draft II was tested at the research site at MAN Labuhanbatu, hereinafter referred to as trial I. Trial I was conducted in class XI Sains of 2 with the number of students 36 students. Trial I conducted 4 meetings in accordance with the lesson implementation plan that had been developed. Trial I was conducted to measure the practicality and effectiveness of learning devices (draft II) developed through problem based learning model assisted by Geogebra was aimed to improve students' mathematical critical thinking abilities.

Overall, the results of the analysis of trial I data are the devices developed that had fulfilled all the practical criteria, but have not yet fulfilled the effective criteria set, namely the results of the posttest mathematical critical thinking ability of students in trial I have not fulfilled the criteria for completeness of classical achievement, achievement of learning objectives has not reached the specified criteria. However, an indicator of effectiveness achieved is the achievement of learning time, that is the learning time used during trial I is the same as ordinary learning. In addition students respond positively to the components of learning devices developed.

Based on the results of the analysis and trial I, it is necessary to revise some of the components of learning device that are developed in the hope that learning device through problem based learning model assisted by Geogebra can improve students' mathematical critical thinking abilities.

The results of the trial I used as a reference to improve the learning device developed. The results of the revision in the trial I produced a draft III which will be tested on XI Sains 1 at MAN Labuhanbatu students, amounting to 36 students. Trial II was conducted 4 (four) meetings in accordance with the lesson implementation plan that had been developed. Trial II was conducted to measure the effectiveness of learning device (draft III) developed through problem based learning model assisted by Geogebra which aims to improve students' mathematical critical thinking abilities.

Overall, the results of the analysis of the trial II data is that the learning device developed have been effective, such as the results of the posttest mathematical critical thinking ability of students in the trial II had fulfilled the criteria of achieving classical completeness, the achievement of learning objectives that have reached specified criteria, the achievement of learning time is not beyond learning can have been achieved and student responses to positive learning.

Thus, it is known that the results of trial II are better than trial I, then based on the results of trial II it can be concluded that the learning device through problem based learning model assisted by Geogebra had fulfilled the quality of practical and effective learning device.

4.1.4. Disseminate

The development of learning device has reached the final stage where learning devices have received positive assessments from experts and through development tests. After the valid, practical and effective criteria are fulfilled in trial II, Draft final is obtained. The next step is to do a limited distribution in the form of final distribution to MGMP forums in MAN Labuhanbatu which is marked by the delivery of learning device developed to the MGMP forum in the hope that the mathematics teacher incorporated in the forum can apply these learning device to further learning in order to improve critical thinking skills mathematically students.

4.2. Result of Trial I

Based on the results of data analysis in trial I, it was found that the learning device developed had fulfilled the

specified practical criteria, namely: (1) the results of expert assessments, the components of the learning device developed were practical/ could be used with minor revisions; (2) teachers and students who state that the learning device developed are easy to use; (3) the implementation of the learning device had fulfilled the specified criteria, which has reached the good category $(80 \le k < 90)$.

But the learning device developed had not fulfilled the established effective criteria, because there are still several indicators of effectiveness that have not yet been achieved. Based on the results of the posttest analysis of students' mathematical critical thinking skills in the first try, it was found that the percentage of classical mathematical critical thinking skills was 69.44%. This states that students have not fulfilled the classical completeness criteria.

Furthermore, for the criteria of achievement of learning objectives, one of the four items of the students' mathematical critical thinking ability test items has not yet reached the specified criteria but there are three test questions for the ability to think critically mathematically that have been achieved in the first tryout.

The effectiveness indicator that has been fulfilled in the first trial is the achievement of learning time, namely the length of learning time using the learning device through problem based learning model assisted by Geogebra is the same as the usual learning time carried out so far, besides that students respond positively to learning through problem based learning model assisted by Geogebra with an average positive response of students in trial I was 88.98%.

4.3. Result of Trial II

Based on the analysis of data in Trial II, it was found that the learning device developed had fulfilled the effective criteria. Based on the results of the posttest analysis of students' mathematical critical thinking skills in the second trial it was found that the percentage of classical mathematical critical thinking skills was 91.67%. It states that students had fulfilled the classical completeness criteria. Furthermore, for the achievement criteria of learning objectives, the four items of the students' mathematical critical thinking ability test items have reached the specified criteria.

Likewise, the indicators of learning time achievement, namely the length of learning time using the problem based learning model assisted by Geogebra, are the same as the normal learning time done so far, in addition students respond positively to learning through problem based learning model assisted by Geogebra with average the average positive response of students in trial II was 94.63%.

4.4. Description of Increasing Students' Mathematical Critical Thinking Abilities Through Problem Based Learning Model Assisted by Geogebra

Data obtained from the results of the pretest and posttest mathematical critical thinking ability of the first trial and the second trial were analyzed to determine the increase in students' mathematical critical thinking abilities. The improvement of students 'mathematical critical thinking skills in the first tial will be seen through the N-Gain from the results of the pre-test and post-test students' mathematical critical thinking abilities in the first trial. N-Gain summary results Students' mathematical critical thinking skills can be seen in Table 3, below:

Table 3. Summary of N-Gain Results of Students' Critical Mathematical Thinking Ability in Trial I

N-Gain	Interpretation	Total Students
g ≤ 0,3	Low	12
0,3 < g ≤ 0,7	Medium	20
g > 0,7	Height	4

Based on Table 3, it can be seen that 4 students received N-Gain scores in the range> 0.7 or experienced an increase in students' mathematical critical thinking skills in the "High" category. For students who have increased mathematical critical thinking ability of students with the category "Medium" or get an N-Gain score of 0.3 <g ≤ 0.7 totaling 20 people and 12 people who received an N-Gain score of g ≤ 0.3 with the category " Low". So, the average gain in trial I was obtained 0.4 in the medium category. So, it can be concluded that there is an increase in students' mathematical critical thinking skills after applying learning through problem based learning model assisted by Geogebra in the first trial.

Hereinafter, the improvement of students 'mathematical critical thinking skills in the second tial will be seen through the N-Gain from the results of the pre-test and post-test students' mathematical critical thinking abilities in the second trial. N-Gain summary results Students' mathematical critical thinking skills can be seen in Table 4, below:

Table 4. Summary of N-Gain Results of Students' Critical Mathematical Thinking Ability in Trial II

N-Gain	Interpretation	Total Students
g ≤ 0,3	Low	4
0,3 < g ≤ 0,7	Medium	22
g > 0,7	Height	10

Based on Table 4 above, it can be seen that 10 students received N-Gain scores in the range> 0.7 or experienced an increase in mathematical critical thinking skills of students in the "High" category. For students who have increased mathematical critical thinking ability of students with the category "Medium" or get an N-Gain score of 0.3 <g 7 0.7 totaling 22 people and 4 people who received an N-Gain score of g ≤ 0.3 with the category " Low". So, the average gain in trial II obtained 0.6 in the medium category. So, it can be concluded that there is an increase in students' mathematical critical thinking skills after applying learning by using through problem based learning model assisted by Geogebra in the second trial.

4.5. Discussion

From the results of the validation, the average value of total validation for: (1) Learning Implementation Plan is 4.42; (2) Teacher's Book 4.39; (3) Student Book of 4.41 and (4) Student Worksheet of 4.38. Based on the validity

criteria, it can be said that the developed learning kit is valid. This is in accordance with the research results of [29] that the learning device through problem based learning model assisted by Geogebra that were developed meet valid criteria. Valid illustrated from the results of the validator's assessment that all validators stated both are based on content (according to the curriculum), construct (according to the characteristics/ principles of learning) and language (in accordance with applicable language rules, namely enhanced spelling).

The results of the assessment of the practicality of learning device are obtained from expert/ practitioner assessments which state that the developed learning device can be used with little or no revision. Based on the results of expert assessments, the components of learning device developed in the form of learning implementation plans, teacher books, student books, student worksheets, tests of students' critical mathematical thinking skills are practical/ can be used with minor revisions. Then, in terms of teachers and students stating that the learning device developed are easy to use. Then, the practicality criteria which are reviewed from the implementation of the learning device in this study, also meet the practical criteria. In the first trial, the implementation of the learning device had fulfilled the specified criteria, which were good $(80 \le k < 90)$ and very good $(k \ge 90)$ in the second trial. This is supported by the results of Dahlia's research which shows that the development of learning device through problem based learning model assisted by Geogebra approaches that are developed meets practical criteria [30]. Thus the learning device through problem based learning model assisted by Geogebra developed is easy and can be implemented by teachers and students.

Based on the results of trial I and trial II, the learning device through problem based learning model assisted by Geogebra of developed had fulfilled the specified effective category. From the results of the posttest analysis stated earlier that in trial I the percentage of classical completeness in mathematical critical thinking ability was 69.44% while in trial II the percentage of completeness in classifying mathematical critical thinking ability was 91.67%. If seen from the results of classical student learning completeness students' mathematical critical thinking ability, completeness obtained from the results of the first trial did not meet the classical completeness criteria while in the second tryout fulfilled the classical completeness criteria.

The results of the study above indicate that the mastery of student learning classically with the learning device developed meets the effectiveness criteria. This is because by applying the learning device through problem based learning model assisted by Geogebra students are actively involved in solving problems. This is supported by the results of Tanjung and Nababan's research which concludes that learning device developed with PBL meet the effective criteria indicated by the completeness of individual and classical learning students are fulfilled [31].

This is reinforced by Vygotsky's view that intellectual development occurs when individuals are faced with new and challenging experiences, and when they try to solve the problems raised by these experiences. In an effort to gain understanding, individuals try to link new knowledge with the initial knowledge they already have and then build new understanding. Vygotsky stated that knowledge will be built through experience and the environment around students. In this experience, individuals associate new knowledge with previous knowledge and construct new meanings.

Same thought with Bruner related to the Problem Based Learning model, namely the idea of scaffolding. Bruner describes scaffolding as a process when students are helped to solve a particular problem beyond the student's developmental ability through the help (scaffolding) of the teacher, friend or person who is more mastered. With the existence of assistance (scaffolding) by the teacher in the early stages of learning and negating the assistance as they complete their assignments, the more active students will be in handling their learning assignments which will result in more effective learning done and have an impact on students' mastery of learning classically.

Based on the results of previous research and research support above, it appears that learning device through problem based learning model assisted by Geogebra developed can help students achieve classical learning completeness. Thus it can be concluded that, the learning device through problem based learning model assisted by Geogebra is able to help students achieve classical learning completeness.

Based on the results of data analysis the achievement of learning objectives in the first trial obtained that three of the four items of students' mathematical critical thinking ability tests have been achieved based on specified criteria and there is only one mathematical critical thinking ability ability test that has not been achieved. Whereas in the second trial, all items of the mathematical critical thinking ability test items have reached the specified learning objectives. So it can be concluded that the achievement of learning objectives through problem based learning model assisted by Geogebra of learning device developed has been achieved for each item after testing II.

It is natural that the achievement of learning objectives by using the learning device through problem based learning model assisted by Geogebra had fulfilled the effectiveness criteria. This is because by using problem based learning model assisted by Geogebra during the learning process, students are involved in authentic investigations, namely problem based learning requires students to carry out authentic investigations to find real solutions to real problems. This is in line with Ausubel's learning theory. Ausubel distinguishes between meaningful learning (learning meaningfull) with roteearning learning. Meaningful learning is a learning process where new information is linked to the understanding structure that is already possessed by someone who is learning. Learning to memorize is needed when someone obtains new information in knowledge that is completely unrelated to what he already knows. The same thing also expressed Piaget who considers that mathematics is not accepted passively mathematics is formed and actively discovered by students. Piaget also thinks that the learning process is an active process because knowledge is formed from within the learning subject so that an atmosphere is needed that allows interaction between subjects learning [32]. Piaget's Theory views the knowledge that is built in a child's mind as a

result of active interaction with his environment through the process of assimilation (the absorption of any new information into his mind) and the process of accommodation (the ability to rearrange the structure of his mind because there is new information received). This is reinforced by [30] concluded that the learning device through problem based learning model assisted by Geogebra developed was effectively seen from the completeness of the learning objectives. So it can be concluded that the learning device through problem based learning model assisted by Geogebra are able to help students achieve their learning goals.

Based on the achievement of learning time carried out during trials I and II, the length of learning time using the learning device through problem based learning model assisted by Geogebra is the same as the normal learning time carried out so far, namely 4 (four) meetings or 8 x 45 minutes. Thus it can be concluded that the achievement of learning time for trials I and II have fulfilled the specified time achievement criteria.

Theoretically, the learning time used at the time of learning by using the learning device through problem based learning model assisted by Geogebra had fulfilled the effectiveness criteria. This is supported through [30] concluding that the learning device through problem based learning model assisted by Geogebra developed was effectively seen from the time spent in efficient learning. So it can be concluded that the learning device through problem based learning model assisted by Geogebra is reviewed in terms of time efficiency.

Based on the results of the data analysis of the results of the trial I and trial II it was found that, the average percentage of student responses in each trial was positive. This means students give a positive response to the components of learning device that are developed. Student responses given at each trial have reached the predetermined criteria category that is ≥80%. This shows that, learning device through problem based learning model assisted by Geogebra that have been developed had fulfilled the effective criteria in terms of student responses. According to [33] learning is a process of change that is a business process carried out by someone to obtain a change in new behavior as a whole as a result of interaction with the environment. This is because the learning process is a complex matter, where students determine whether they will learn or not. This is reinforced by [31] which shows that students respond positively to learning by using Mathematics Learning Device of Problem-Based Learning Model (PBM) to Improve Critical Thinking Ability of High School Students in Kuala Nagan Aceh.

Based on the results of the research and supporting research, it can be concluded that the components of the problem based learning model assisted by Geogebra developed contribute positively to students' responses in learning.

Based on the results of an analysis of increasing students' mathematical critical thinking skills in the first trial and the second trial showed that the average mathematical critical thinking ability of students on the results of the pretest trial I was 60.03 and increased in the posttest of trial I to 77.91. Then in the second trial obtained the average results of students' mathematical critical thinking skills in the pretest trial II amounted to 64.02 and again increased in the posttest of trial II amounted to 86.07. Thus, an increase in the average value of students' mathematical critical thinking skills by 17.88 in the first trial and an increase of 22.05 in the second trial. Meanwhile, the increase in the results of the posttest of trial I to trial II was 8.16.

Then when viewed based on N-Gain calculations to see an increase in students' mathematical critical thinking skills in the first trial and the second trial increased, from 0.4 to 0.6, meaning that it is in the category of "medium". This shows the ability of students to think critically mathematically using learning device developed through problem based learning model assisted by Geogebra has increased in the first trial to the second trial.

5. Conclusion

Based on the results of the analysis and discussion in this study, it can be concluded that the learning device through problem based learning model assisted by Geogebra had fulfilled valid, practical and effective criteria and the ability to think critically mathematically students has increased. This research has shown that the development of learning device is an important thing that needs attention in an effort to maximize students' mathematical critical thinking skills. Thus, mathematics teachers are expected to be able to use this learning device as an alternative learning to develop students' mathematical critical thinking skills.

References

[1] Depdiknas. (2006). Permendiknas Nomor 22 Tahun 2006 tentang Standar Isi untuk Satuan Pendidikan Dasar dan Menengah. Jakarta: BNSP

[2] Cockroft. W. H. (1982). Mathematics Counts, Report of the Committee of Inguiry Into the Teaching of Mathematics in Schools. London: Her Majesty's Stationery Office.

[3] Siagian, P. Simanjuntak, E. & Samosir, K. (2016). Prototype Pembelajaran Matematika SMA Sesuai Kurikulum 2013 untuk Meningkatkan Kemampuan Pemecahan Masalah di Provinsi Sumatera Utara. *Jurnal Penelitian Bidang Pendidikan*, 22(2): 91-108.

[4] Syahrir. (2016). Pengembangan Perangkat Pembelajaran Matematika SMP untuk Meningkatkan Kemampuan Berpikir Kreatif. *Jurnal Ilmiah Mandala Education (JIME)*, 2(1): 436-441.

[5] Permendikbud. (2016). Salinan Permendikbud Nomor 22 Tahun 2016 Tentang Standar Proses Pendidikan Dasar dan Menengah. Jakarta: Permendikbud.

[6] Ennis, R. H. (1996). Critical Thinking. USA : Prentice Hall, Inc

[7] Jumaisyaroh, T., Napitupulu, E., E. & Hasratuddin. Peningkatan Kemampuan Berpikir Kritis Matematis dan Kemandirian Belajar Siswa SMP melalui Pembelajaran Berbasis Masalah. *Jurnal Kreano*, 5(2): 157-169.

[8] Istianah, E. (2013). Meningkatkan Kemampuan Berpikir Kritis dan Kretaif Matematis dengan Pendekatan Model Eliciting Activities (MEAs) Pada Siswa SMA. Infinity *Jurnal Ilmiah Program Studi Matematika STKIP Siliwangi Bandung*, 2(1): 43-54.

[9] Sari, A., N., Wahyuni, R. & Rosmaiyadi. (2016). Penerapan Pendekatan Open-Ended untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Pada Materi Aljabar Kelas VIII SMP Negeri 10 Pemangkat. *Jurnal Pendidikan Matematika Indonesia*, 1(1): 20-24

[10] Marbun, M., S., P., Siagian, P., Mansyur, A. (2018). Development of Learning Devices Using Model Problem Based Learning To Improve Problem Solving Abilities Senior High Scool. *Atlantis Press*, 3(200): 382-384.

[11] Lestari, K., E., dan Yudhanegara, M., R. (2017). *Penelitian Pendidikan Matematika*. Bandung: Refika Aditama

[12] Sugiarni, R., Algifari, E., & Ifanda, R., A. (2018). Meningkatkan Kemampuan Spasial Matematis Siswa Dengan Model Pembelajaran Problem Based Learning Berbantuan Geogebra. *Kalamatika Jurnal Pendidikan Matematika*, 3(1): 93-102.

[13] Delisle, R. (1997). How to use problem-based learning in the classroom. Alexandria: ASCD.

[14] NCTM. (2000). *Principles and Standards for School Mathematics*. ISBN: 0-87353-480-8. America: The United State of America.

[15] Putri, N. W., Candiasa, I.M., Suweken, G. (2016). Pengembangan Media Pembelajaran Transformasi Berbasis Geogebra. Jurnal Wahana Matematika dan Sains, Volume 10, Nomor 2, Oktober 2016.

[16] Herawati, L. (2017). Peningkatan Kemampuan Koneksi Matematis Peserta Didik Menggunakan Model Problem Based Learning (PBL) dengan Berbantuan Software Geogebra. *Jurnal Penelitian Pendidikan dan Pengajaran Matematika*, 3(1): 39-44.

[17] Khoiri, W., Rochmad, R. & Cahyono, A., N. (2013). Problem Based Learning Berbantuan Multimedia Dalam Pembelajaran Matematika Untuk Meningkatkan Kemampuan Berpikir Kreatif. *Unnes Journal of Mathematics Education*, 2(1):114-121.

[18] Sugiarto, W., (2017). Penerapan Pembelajaran Berbasis Masalah Berbantuan *Geogebra* Untuk Meningkatkan Motivasi dan Prestasi Belajar Materi Komposisi Transformasi. *Jurnal of Medives*, 1(1): 42-48.

[19] Hohenwarter, M., Hohenwarter, J., Kreis, Y. & Lavicza, Z.. (2008). *Teaching and Learning Calculus with free dynamic mathematics software Geogebra.* (Online). Avaible: http://www.geogebra.org/publications/2008-ICME-TSG16-CalculusGeoGebra-Paper.pdf. [Accessed 9 Nopember2018].

[20] Ekawati, A. (2016). Penggunaan Software Geogebra dan Microsoft Mathematic dalam Pembelajaran Matematika. *Jurnal Pendidikan Matematika*, 2(3): 148-153.

[21] Splitter, L. J. 1991. Critical Thinking: What, Why, When, and How. *Educational Philosophy and Teory.* 23(1): 89-109.

[22] Facione, P. A. (1992). *Critical Thinking: What It Is and Why It Counts*. (Online). Avaible: http://www.student.uwa.edu.au. [Accessed 9 Nopember 2018].

[23] Noordyana, M., A. (2016). Meningkatkan Kemampuan Berpikir Kritis Matematis Siswa Melalui Pendekatan Metacognitive Instruction. *Mosharafa*, 5(2): 120-127

[24] Amalia, E., Syahputa, E., Surya, E. 2017. The Effectiveness of Using Problem-Based Learning (PBL) In Mathematics Problem Solving Ability for Junior High School Students. *IJARIIE. 3(1): 3402-3406*.

[25] Syahrir, Susilawati. (2015). Pengembangan Modul Pembelajaran Matematika SMP. *Jurnal Ilmiah Mandala Education (JIME)*, 1(2): 162-171.

[26] Priyono, S. & Hermanto, R. (2015). Peningkatan Kemampuan Representasi Matematik Peserta Didik dengan Menggunakan Model Probleblem Based Learning (PBL) Berbantuan Media Software Geogebra. *Jurnal Penelitian Pendidikan dan Pengajaran Matematika*, 1(1): 55-64.

[27] Thiagarajan, S. Semmel, D.S & Semmel, MI. (1974). *Instructional Development for Training Teachers of Exceptional Children*. Indiana: Indiana University Bloomington.

[28] Nieveen. N. & Folmer. E. (Eds.). (2013). *Educational Design Reseach*. The Netherlands: SLO Enshede.

[29] Hasibuan, N. H. (2016). Perbedaan Kemampuan Berpikir Kritis Matematis dan *Self Efficacy* Siswa Antara Pembelajaran Berbasis Masalah Berbantuan *Geogebra* Dengan Pembelajaran Berbasis Masalah Berbantuan *Autograph* Di MAN 1 Medan. Tesis tidak diterbitkan. Medan: Program Studi Pendidikan MAtematika Pascasarjana Universitas Negeri Medan.

[30] Dahlia. (2016). Pengembangan Perangkat Pembelajaran Model PBL Berbantuan Geogebra untuk Meningkatkan Kemampuan Pemeahan Masalah Matematis dan Kemandirian Belajar Siswa SM Negeri 3 Langsa. Tesis Unimed. Tidak diterbitkan.

[31] Tanjung, H., S. & Nababan, S. A. (2018). Pengembangan Perangkat Pembelajaran Matematika Berorientasi Model Pembelajaran Berbasis Masalah (PBM) untuk Meningkatkan Kemampuan Berpikir Kritis Siswa SMA Se-Kualuh Nagan Raya Aceh. *Genta Mulia*, IX(2): 56-70.

[32] Sumarli, Nugroho, S., N. & Yulianti, I. (2018). Keefektifan Model Pembelajaran Creative Problem Solving Berpendekatan Inquiry Terhadap Keterampilan Proses Sains Siswa. *Physics Communication*, 2(1): 63-69.

[33] Daryanto. (2013). Inovasi Pembelajaran Efektif. Bandung. Yrama Widya.