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Enhancing Students' Critical Thinking Ability in Mathematics by Through IMPROVE Method

Bambang Sri Anggoro[1]* Yaya S. Kusumah[2] Darhim[2] Jarnawi D. Afgani[2]
1. Raden Intan State Institute for Islamic Studies, Jl. Letkol. H. Endro Suratmin, Sukarame, Bandar Lampung, Lampung 35131, Indonesia
2. Indonesia University of Education, JL.Dr Setiabudi No. 229,Bandung,West Java,40154, Indonesia
*E-mail of the corresponding author: bambangsrianggoro@gmail.com

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Abstract

This study aims to figure out the students' enhancement of critical thinking ability in mathematics by using IMPROVE and conventional methods. It is a quasi experiment and the population is the students of two junior high schools (JHC) with intermediate level of knowledge in Bandar Lampung City. The samples are two student groups at Grade VIII taken from two grades of each JHC randomly. The instrument employed in this study is a test in mathematical critical thinking ability. Data analyses operate T-test and two-way ANOVA. The results show that the students' mathematical critical thinking ability under IMPROVE method are better than students under conventional one. In the IMPROVE method, group students at upper level possess more better accretion of mathematical critical thinking ability than students at middle and low levels. On the other hand, the proliferation of mathematical critical thinking ability possessed by students at lower level is better than students at middle level. It is found that there is a difference of critical thinking ability augmentation between upper level, middle level, and lower level of students under IMPROVE method. There is an interaction between learning factor and student's competence category toward of their mathematical critical thinking.

Keywords: mathematical critical thinking ability and IMPROVE method

1. Background

Critical thinking emphasizes on the importance of planning strategy in solving problems in various ways, giving ideas, and comparing solution strategies to student's prior experiences or theories. Constructing ideas and making inferences need to be conducted by the students when they have choosen the strategy. The enhancement of students' idea can be increased and detailed by object, idea, or situation. After such phase, students will gain solution which needs to be verified and used to develop alternative strategy**.**

Noticeable difference appeared in practice. Theories explained are far different from reality in practice. The real competence of JHC students in solving mathematical problems, enhancing critical thinking abilty, and metacognitive competence are inadequate. This can be shown in the findings on *The Trends in International Mathematics and Science Study* (TIMSS) and *Program for International Students Assessment* (PISA).

In TIMSS competition, Indonesian contestants' competence is still low in solving irregular items relating to establishing truth or proving, solving problems by using reasoning, thinking critical, doing metacognitive competence, finding generalisation or conjectur, and finding correlation between the given data and facts. However, they are relatively better in solving factual and procedural items (Noer, 2010). As a result, in TIMSS (1999, 2003, 2007, 2011) and PISA (2000, 2003, 2006, 2009) the results shows no significant changes in every participation. In PISA (2009) Indonesia held 61st position from 65 participants with average score 371, compared to the average international score 496. Unfortunately, in TIMSS (2007), they scored lower than the former participation, which is 405, compared to the score in 2003,

namely 411. Indonesia's rank in TIMSS (2007) held 36th position from 49 participant countries (Ministry of National Education, 2011).

In the PISA (2009) for Grade VIII students, Indonesia held 61st position from 65 participants (Ministry of National Education, 2011). Items given to the students in this study did not directly relate to the school curriculum topics, but the items were focused on *mathematical literacy*. It is proved that the students apply mathematics that they have studied to solve their daily problems that need reasoning, critical thinking, metacognitive and communicative competences. This exhibits Indonesian students have low ability in processing component including thinking and heuristic abilities as well as metacognition component.

Learning mathematics with enhancing metacognitive competence is a method that emphasizes on students learning activities. Teachers work as facilitators to assist and guide students to develop their metacognition awareness. Metacognition process is strategy of students' self-regulation in selecting, memorizing, recalling, organizing information and solving the problems. Metacognition is also defined as a theory that constructs individuals' awareness in their thinking process. Therefore, having metacognition competence, students are expected to be aware of their strength and weakness in learning. This means that when students find out their mistakes, they correct themselves and soon be aware of how they should do (Elawar in Nindiasari, 2004).

Students' metacognition does not simply mean they have competence in comprehending working steps, but also how they are aware of the process they experienced since the learning with this approach is able to improve student's high-level critical thinking ability. This is why the students are demanded to apply their critical thinking ability. Therefore, student's critical thinking ability will be developed. As Livingstone (1997) said, metacognition refers to high level critical thinking ability involving the control of cognitive process in learning.

At the transitional phase, students are taught to start practicing hypothetical, proportional, evaluative, analytic, synthetic, critical, and logical thinking as well as be able to comprehend concepts abstractly. In addition, if we have seen student's mental enhancement, the JHC students are able to be stimulated to think in higher level reasoning, i.e. thinking critically. To best work, learning method should be synchronized to the JHC student's level of thinking.

Teaching students' by utilizing self-metacognition, abilities that assist themselves in solving problems relating to other disciplines as well as their daily experiences. Based on JHC students' metacognition enhancement that starts entering formal thinking phase, the researcher is interested in figuring out the influence of IMPROVE learning method to JHC students' cognitive enhancement. IMPROVE learning method is a method of learning that emphasizes the enhancing metacognitive competence and critical thinking ability. This is reflected in one of the learning steps of IMPROVE, i.e. *metacognitive questioning*. Learning steps is an enhancement of student thinking process through awaring of what they have comprehended. Therefore, it will indirectly affect the student critical thinking ability.

2. Critical Thinking in Mathematics

Ennis (in Sabandar, 2009a) suggests six basic elements that are necessarily considered in critical thinking:

2.1 *Focus* on situation or condition that displays and describes main problem. Focus on the main problem is able to be conducted by questioning: What happen/find out? What is the main problem indeed? How to prove it? What is the solution?

2.2 *Reasons* underpin arguments that support making inference, finding facts and evidences that support reasons of making inferences so the inference would be true and can be acceptable, as well as identifying and justifying the problem. Reasons as mentioned should be related to the main problem in order to decide and consider any possible options, to investigate and to study problem more detail as well as making inference. Everything is not only conducted for the start and the end of the process, but in solving problems with all learning process.

2.3 *Inference* questions and considers any proposed reasons. Are the reasons accurate and true? If they are, are the reasons strong and useful in making inference?

2.4 *Situation* is condition or situation of environment around us. Situation can affect individual in performing thinking activity and making inference.

2.5 *Clarification* is an act of inquiring considerations and analogies made from available information. Questions of clarifying would be: What does the inference mean? Could other methods be used? Could it give another example? Could itu give other description?

2.6 *Overview* is a process of comprehending all sides of the problem, conclusion and solution to the problem.

Another opinion is suggested by Baron and Sternberg (1987: 10). They argue five principles in critical thinking: reflective, practical, reasonable, believable, and active. Based on their opinion, critical thinking may be defined as a reflective and reasonable practical thinking aimed at or focused on deciding what is believed to do in action.

3. IMPROVE Method

IMPROVE method stands for every learning steps introduced by Kramerski (Mevarech & Armany, 2008).

3.1 Introducing the new concepts

The first letter of IMPROVE is *introducing the new concept*. Introducing new concept in IMPROVE learning method differs from introducing new concept in traditional method. In traditional learning method, a teacher introduces a new concept by delivering speech in front of the classroom while students listen to what he/she explains. It is called teacher-centered learning. In IMPROVE method, the teacher does not olny give input or output to the students, but he/she also gives the new materials by asking them questions which make students be active in learning process in order that students can recognize their knowledge. Questions are provided by teacher to guide the students in comprehending the concepts or materials they are being taught. For instances, *What formula do you know? How do you apply the formula?*, etc.

3.2 Metacognitive questioning

Teacher asks metacognitive questions, such as *what*, *why*, and *how*. Kramerski (Mevarech & Armany, 2008) suggests that the questions would be: knowledge problems, relational enhancement between prior and present knowledge, proper strategy application for solving problems, and question reflection for solving problem. Metacognitive questions are questions proposed by teacher to the students. These followings are types of metacognitive questions that can be asked by teacher to the students (Mevarech & Kramarski, 2008):

3.2.1 Knowledge Question

This question relates to the theory taught in teaching-learning process. For example, “What is the whole problem about?” It also relates to the understanding of theory being

solved. For instance, a teacher provides a problem to the students about one topic. Then, he/she asks, "What is the problem?" At this point, student's metacognition is active. Students think and answer the question. Students sort all materials they have learned and find the answer.

3.2.2 Relational Question

The question is connecting question what students have learned at present to what students have learned from the past. For instance, "Are the present and the past problems similar to or different from what you have learned before? If the students answer to this question, their metacognition will indirectly be active. The students will recall their past experience, how they solve the problems, and compare them to the new problems.

3.2.3 Strategic Question

This question relates to solutions that students proposed in solving the problems they met. This will stimulate students to find out the best or alternative solution in solving the problems. For instance, "What strategy does solution fit to the problem and why?" Asking this question makes students to think automatically what the best way to answer the question is. Moreover, the students also need to know the reason why they choose the strategy. These will drill students in expressing their opinion.

3.2.4 Reflective Question

Reflective question encourages students to reconsider method or strategy that they have proposed, i.e., "Is the strategy make-sense solution to solve this problem?" At this point, students reconsider the proposed solution. This aims to make students be careful in answering various questions.

3.3 Practicing

After presenting knowledge questions, students, are asked metacognitive questions. Furthermore, students are asked to practice problem solving directly. It best benefit for improving material mastery and drill students' competence and skill because learning by doing is better than learning by reading and listening. Teacher provides items for student to practice solve problem.

3.4 Reviewing and Reducing Difficulties

Usually, students are challenged with many problems in practicing. At this step, teacher tries to review any mistakes students made in understanding the materials and try to answer the question. After that, teacher provides solution to the problem.

3.5 Obtaining mastery

After accomplishing the teaching-learning process, teacher gives tests to the students. This test aims at knowing the student mastery on the materials they have learned. The results will help teacher to know which students have master the material and which one have not yet.

3.6 Verification

After testing and finding out the result, teacher makes identification in order to classify students who have passed the passing grade and students who have not done yet. The former is categorized to master the material and the latter to do not master the materials yet.

3.7 Enrichment and remedial

The final step of IMPROVE learning method is remedial. It is for students who have not mastered the materials yet. This is carried out through remedial.

4. Methodology

This study is a quasi experiment because the researcher provides treatment to the subjects of study. It is intended to find out the effect of the treatment. But then, the subjects are not grouped randomly, but the researcher takes them as they are. This design is applied in considering that the class has been assembled priorly. Therefore, it does not need to group them randomly.

This study takes two classes, one as experimental class and the other one as control class. The former is provided IMPROVE learning method and the latter is provided conventional one. The treatment will be the application of IMPROVE learning method. It is to find out its effect to the variable of student's critical thinking and mathematical disposition. The independent variable is IMPROVE learning method, the dependent variables is critical thinking ability, and the control variable is student's initial knowledge (upper level, middle level, and lower level).

Study design comprises as follows:

Experimental Group	O	X	O
Control Group	O		O

Population is students of two junior high schools in Bandar Lampung in academic year 2012/2013's. The samples chosen randomly consist of two groups of Grade VIII students which are taken from two classrooms of each school. Random sampling method is chosen in order to get two classrooms from two schools that have the same level of knowledge.

Data collection employs two instruments: (1) test comprises of a set of items to measure and to find out the initial mathematics knowledge of the students, i.e. critical thinking test and (2) mathematics final test score of Grade VIII students.

5. Findings and Discussion

The result displays method of IMPROVE have effect on the critical thinking ability of the students in mathematics. The effect is shown by the difference of average score of *post-test* of critical thinking ability in mathematics gained by students who are in a group given IMPROVE learning method and group given conventional learning method. After giving IMPROVE method to the students of experimental group and conventional method to the students of control group, the result confirms the first hypothesis suggesting that critical thinking ability in mathematics of students under IMPROVE method is better than the ability of the students under conventional one. This study is relevant to Magno's study (2010) suggesting that critical thinking ability of the student in mathematics for groups under metacognitive learning is better than the group not given any treatment. The research was carried out to study the metacognition method. Metacognition is one of the steps in IMPROVE method. In short, the notion becomes a relevant theory that can affect critical thinking ability in mathematics.

Based on the pre-test score analysis, it is found that the initial critical thinking ability in mathematics of experiment and control group is significantly not different. It can be exposed the pre-test score gain and average differential test of pre-test score on the two groups. The average pre-test score of critical thinking ability in mathematics of the experimental students is 4.643 or 12.897% from ideal score with highest score 11, lowest score 1 and standard deviation 2.297. The average pre-test score of critical thinking skill in mathematics of the control students is 4.261 or 11.836% from ideal score with highest score 10, lowest score is 0 and standard deviation is 2.207. The results of pre-test scores are different. However, the results of average differential test by statistical analysis show that hypotesis H_l—a significant difference between initial critical thinking ability of the experimental students and the control

students—is rejected. This means that teaching-learning treatment has been given to the two groups of students with no significant difference in skill.

After applying IMPROVE method to the experimental students and conventional method to the control students, it is exposed the post-test scores of critical thinking ability in mathematics of the both group. The average post-test score of critical thinking ability in mathematics of experimental students is 17.157 or about 47.6584% from the ideal score with the highest score is 30, the lowest score is 8, and standard deviation is 6.257. The average post-test score of the control group of students is 12.797 or equal to 35.547% from the ideal score with the highest score is 27, the lowest score is 4, and standard deviation is 5.215. Based on the standard deviation, it is found that the post-test score of control students is much centered on average score compared to the experimental students. Based on post-test score of critical thinking ability in mathematics of experimental and control students, it is found that the post-test score of the experimental students is centered to 30 to 8, while the control students' score is centered to 27 to 4. Although the post-test score of the control students is more homogenous than the score of the experimental students, the average result of differential test revealed that the average score of post-test of critical thinking ability in mathematics of experimental students is better than the control students score. As a result, it can be established that critical thinking ability in mathematics of students under IMPROVE method is significantly better than the students' ability under conventional method.

The test of the difference of critical thinking ability average displays critical thinking ability in mathematics of students provided with IMPROVE learning method is significantly better than the students given conventional method. However, generally the average score of critical thinking ability in mathematics of students did not reach 50% of the ideal score. This may actually be caused by various external factors in teaching-learning process. Based on unsystematic observation, it is found that the students did not use to practice critical thinking in mathematics. The items given were usually regular which only ask the end answer without asking the step and process of critical thinking. Most of the items are also in multiple choices. The items did not practice the student's critical thinking in mathematics and thinking awareness. The treatment was only applied in three months. It was relatively short and certainly affected the teaching-learning process. The student's initial condition which is unfamiliar to critical thinking in mathematics, the application of different method from usual, relatively short time as well as student's adaptation to the researcher caused the student's critical thinking ability in mathematics to be not maximal yet.

The effect of IMPROVE learning method can be seen also from the enhancement of critical thinking ability in mathematics of the upper, middle, and lower level student groups which indicate that the student's ability categories significantly affect the enhancement of critical thinking ability in mathematics. This difference is in line with Galton's opinion (Lindawati, 2010) suggesting that there is a number of students in a group who has individual differences, that is over average, average, and under average abilities.

Another result on the difference of critical thinking ability enhancement in mathematics based on interaction of learning factor with student category factor indicates that there is an influence of interaction between the administered methods with student ability category. In summary, the data related to the average of pre-test, post-test, and critical thinking ability enhancement in mathematics based on learning factor and student category are provided in Table 1.

Table 1 Pre-test, Post-test and Gain Average of Critical Thinking Abilites in Mathematics of Upper, Middle, and Lower Level Students

Methods	Category Average	Pre-test Average	Post-test Average	*Gain*	*Gain Category*
IMPROVE	Upper	7,316	23,895	0,582	Medium
	Middle	4,156	13,938	0,307	Medium
	Lower	2,789	15,842	0,392	Medium
	Total	4,643	17,157	0,405	Medium
Conventional	Upper	5,579	14,526	0,297	Low
	Middle	4,677	14,290	0,304	Medium
	Lower	2,263	8,632	0,194	Low
	Total	4,261	12,797	0,272	Low

Based on the analysis of *gain* score, it is found that gain average of critical thinking ability in mathematics of upper level, middle level, and lower lever students who received IMPROVE method is considered as medium category. The *gain* average of the students at upper and lower level group who received conventional learning method is categorized into low category. The middle level student score gain average is at medium category. The average *gain* of critical thinking ability in mathematics of students received IMPROVE learning method is overall considered to medium category and the average *gain* of critical thinking ability in mathematics of students received conventional learning method is overall considered to low category. This indicates that the enhancement of critical thinking ability in mathematics does not happen to all indicators.

The interaction between learning factor and the initial student's ability indicates that both factors have influence on the enhancement of student's critical thinking ability in mathematics. The interaction of critical thinking ability in mathematics based on learning factor and student ability category factor is shown in Figure 1.

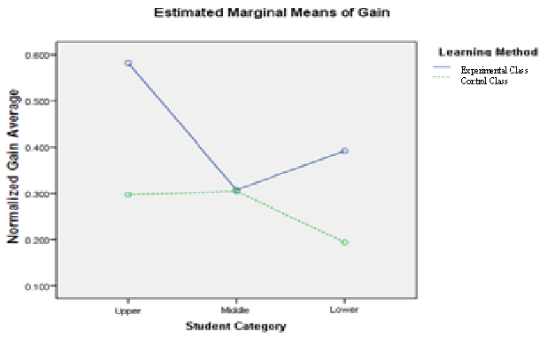

Figure 1. Interactional Graphic of *Gain* Average of Critical Thinking Ability in Mathematics Based on Learning and Student's Ability Category Factors

In Figure 1, it is found that the highest enhancement of critical thinking ability in mathematics is achieved by upper level students who received IMPROVE learning method. Based on the figure, it is shown that lower level student who received IMPROVE learning method achieved *gain* average that is higher than lower level, middle level, and even upper level students who

received conventional learning method. However, the middle level students who received IMPROVE learning method have achieved *gain* score average of critical thinking ability in mathematics that is not much different from group of middle level students who received conventional one. The *gain* score average of critical thinking ability in mathematics of the students who received IMPROVE learning method is 0.307, while students who received conventional one achieved 0.304.

Based on Figure 1 and Table 1, upper level students who received IMPROVE learning method have higher enhancement of critical thinking ability in mathematics than the middle and lower level students have. Based on test result, it is found that the significance degree for gain average difference of critical thinking ability of the upper and middle level students is 0.000. This value is lower than significance degree $\alpha = 0.05$ meaning that there is a different enhancement of *gain* average of critical thinking ability for students at upper and middle levels. The significance degree for the *gain* average difference of critical thinking ability of the students at upper and lower levels is 0.000. This value is also less than significane degree $\alpha = 0.05$ meaning there is a difference of *gain* average enhancement of critical thinking ability for students at upper and lower levels. Based on the Tukey test, it can be identified that students at upper level took more benefit from IMPROVE learning method than students at middle and lower levels. These findings are in line with Mevarech and Kramarski's findings (1997). They suggests that IMPROVE leaning method gave chance for talented students to establish their mathematic sense through metacognition. This is caused by IMPROVE method that allow the teacher to provide assistance for the students to develop their thinking awareness when they overcome problems or understand a new concept. Teacher's help in metacognitive questions can be used by the students at upper level. This is done by asking teacher many questions. As a result, student critical thinking ability in mathematics is improved. Students also develop and recognize the way of thinking to respond to a question.

When practice is given, group activity is also provided in IMPROVE learning method. This will give opportunity to upper group students acting as tutors and guide their group members who have not understood the material or the given problems. The learning situation in practicing IMPROVE method holds important role for upper group students since they have a chance to practice their mathematic critical thinking when explaning about the material to their friends. By giving repeated explanation, the upper group students will increase their knowledge and understanding in critical thinking.

Based on Figure 1 and Table 1, the enhancement of student's critical thinking ability in mathematics of the lower level students who received IMPROVE method is higher than the middle level students have. However, based on *Tukey* test result, it is found that the significance degree for gain average difference of critical thinking ability of the middle and lower level students who receives IMPROVE learning method is 0.893. This value is higher than significance degree $\alpha = 0.05$ meaning that there is no significant difference between the *gain* average enhancement of critical thinking ability for students at upper level and lower level. Based on pre-test score of student's critical thinking ability in mathematics for both student groups in Table 1, it can be identified that pre-test average score of critical thinking ability in mathematics for students at lower level is lower than the middle level; either in group of students who received IMPROVE method or conventional method. These findings suggest that the students at lower level have many chances to improve their critical thinking ability in mathematics. In addition, group interaction also gives more chance for the students at lower level learn from their friends who have already master the materials and tasks (Slavin, 1997).

Student's critical thinking ability enhancement in mathematics at upper level who receives IMPROVE method is higher than the upper level students who receives conventional method. It possibly happens since in IMPROVE method one new concept and problem concerning to thinking awareness enhancement are given to each student. In this method teacher takes role as facilitator by asking metacognitive questions that can lead students trying to realize what condition in their own mind and what problem they are writing, doing, and facing.

Constructive metacognitive questions for student's awareness basically fit to all student groups, but those questions generate more benefits for students with high level competence in mathematics. At upper level group, students can overcome unconfidence and confusion to ask and answer question rather than other groups since they have already achieved prior knowledge to overcome these problems. Therefore, they can manage their unconfidence and fear.

For upper level students who are taught conventional learning method, they basically have knowledge, but the learning process is dominated by teacher. It has always been practiced for many years. Teachers explain more to the students in end output and did not stimulate the students with metacognitive questions. Such condition does not provide chances to the students at upper level to develop their thinking awareness since they are also provided with routine items. In line with Muin's study (2005), he concludes that students receiving method with metacognition approach possess higher mathematic competence and mathematic competence enhancement than students receiving conventional method.

Critical thinking ability enhancement in mathematics at middle level of students instructed with IMPROVE method is higher than that of students instructed by traditional method. However, the result of average differential test demonstrates the two groups have no significant average difference in critical thinking ability enhancement in mathematics with significance degree is 5%. Based on unsystematic observation during the application of IMPROVE method, at the topic of introducing new concept and group discussion, the middle level group students exhibit no dominant involvement in teaching-learning process. There are only a few students asking questions and answering teacher's questions. Whereas, method using IMPROVE method allows the teacher to assist the students in asking questions or to help them realize their mind when facing the problems. The assistance is not employed by the middle level students group.

On the basis of Figure 1 and Table 1, the enhancement of critical thinking ability in mathematics of the lower level students making use of IMPROVE method is higher than the students utilizing traditional method. Based on *t*-test result, it is found that at significance degree $\alpha = 5\%$, the enhancement is statistically significant. It is caused by methodal factors applied in IMPROVE method, such as group discussion and metacognitive questions, whereas group discussion and metacognitive questions are not found in conventional method method. In IMPROVE method, the activities allow interaction among students. Interstudent interaction concerning with proper tasks may improve student's competence on the important concepts. These kinds of interaction differ from the usual interaction. These are metacognitive interaction of all students. The collective metacognitive interaction will generate every student's metacognition individually. Besides, in the group discussion the lower level students possess chances to learn materials from their friends at upper level mastering the materials (Slavin, 1997).

In this study, one of supports asserting that critical thinking ability in mathematics of the students receiving IMPROVE method is better than students receiving conventional method is that experimental students are used to take ask-answer activity between teacher and student. Ask-answer activity is interaction either between teacher and students or among students. Metacognitive questions that they ask to one another are employed as reference to know and realize what problems they are faced with. Another support is in experimental group, teachers review and correct student's mistakes by guiding them through asking several metacognitive questions. The review is carried out after practices are directly provided to the students. Practices are administered as an effort of reflection to concept introduction and ask-answer metacognitive questions. After reviewing, a test is given to students instructed by IMPROVE method so the teacher can figure out student's mastery to the given materials. The test is also used as a basic material to identify which students have mastered materials and which have not. For students who have not mastered the materials yet, they are given remedial by re-explaining the materials and giving practices as well as guiding them to find out the mistakes in answering the questions.

Another advantage of experimental group students—receiving IMPROVE method—compared to control students—receiving conventional method—is to provide opinion by writing and solving an item. The activity is an attempt to know the problem that they face and to realize their mind mapping when they comprehend a concept and answer the question. They also think more creatively and critically in judging their ideas and notions. Students of experimental group are more confident to confirm their ideas that they possess to the teacher. The method also made experimental students to be able to argue and defend their opinions and ideas. The IMPROVE method also allows the students to re-exemine truth of the concept and idea they possess. The question "why" is frequently asked by the teacher either in introducing a new concept or asking metacognitive question. It causes students understand and learn more about the potentials they possess in finding the answer. This also makes students be more careful in thinking and giving ideas since they must be responsible for their ideas through metacognitive question.

When students fail to solve the problems, they will be guided to observe and find out important information in various resources and references concerning to the problem they face. Students are guided to ask and discuss the problem with their group member or with other group members. This discussion activity allows the students to interact, ask question, give opinion, and respond other student's opinion reciprocally. If they can still possess the problem, teacher guides them by using metacognitive questions. At this instance, teacher does not directly answer the student's question, but he/she acts a facilitator in learning process. Students must pass all the process. Eventually, students are able to solve the problem by themselves.

6. Conclusion

On the basis of data analysis, the researcher concludes that critical thinking ability in mathematics of the students receiving IMPROVE method is better than students under conventional method. On the group of students receiving IMPROVE method, the upper level group possessing enhancement of critical thinking ability in mathematics is better than the middle and lower level group. The enhancement of critical thinking ability in mathematics of the lower level students group is better than the middle level group. Therefore, there is a difference of critical thinking ability enhancement in mathematics among students at upper, middle, and lower level receiving IMPROVE learning method. It is also found that there is an interaction between learning factor with student ability category and the enhancement toward students' critical thinking ability in mathematics.

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