International Journal on Emerging Mathematics Education (IJEME)
Vol. 1, No. 1, March 2017, pp. 87-98
P-ISSN: 2549-4996, E-ISSN: 2548-5806, DOI: http://dx.doi.org/10.12928/ijeme.v1i1.5698

Using the 5E Learning Cycle with Metacognitive Technique to Enhance Students' Mathematical Critical Thinking Skills

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Abstrak

Penelitian ini bertujuan untuk mendeskripsikan peningkatan dan pencapaian kemampuan berpikir kritis matematis siswa yang menerima Learning Cycle 5E dengan teknik Metakognitif, Learning Cycle 5E, dan pembelajaran konvensional. Penelitian ini menggunakan metode eksperimen dengan desain kelompok kontrol pretest-posttest. Populasi adalah siswa SMP di Indramayu, Indonesia. Sampel terdiri dari tiga kelas siswa kelas VIII dari sekolah level tinggi dan tiga kelas dari sekolah level sedang. Hasil Penelitian mengungkapkan bahwa dilihat dari siswa secara keseluruhan, peningkatan dan pencapaian kemampuan berpikir kritis siswa yang menerima *Learning Cycle 5E* dengan teknik Metakognitif lebih baik dari siswa yang menerima *Learning Cycle 5E* dan pembelajaran konvensional. Kemampuan berpikir kritis matematis siswa yang menerima *Learning Cycle 5E* lebih baik dari siswa yang menerima pembelajaran konvensional. Tidak ada pengaruh interaksi antara model pembelajaran dan level sekolah terhadap peningkatan dan pencapaian kemampuan berpikir kritis matematis siswa.

Kata Kunci: kemampuan berpikir kritis matematis, learning cycle 5E, teknik metakognitif

Abstract

This study aims to describe enhancement and achievement of mathematical critical thinking skills of students who received the 5E Learning Cycle with Metacognitive technique, the 5E Learning Cycle, and conventional learning. This study use experimental method with pretest-posttest control group design. Population are junior high school students in Indramayu city, Indonesia. Sample are three classes of eighth grade students from high level school and three classes from medium level school. The study reveal that in terms of overall, mathematical critical thinking skills enhancement and achievement of students who received the 5E Learning Cycle with Metacognitive technique is better than students who received the 5E Learning Cycle and conventional learning. Mathematical critical thinking skills of students who received the 5E Learning Cycle is better than students who received conventional learning. There is no interaction effect between learning model and school level toward enhancement and achievement of students' mathematical critical thinking skills.

Keywords: mathematical critical thinking skills, 5E learning cycle, metacognitive technique.

How to Cite: Runisah, Herman, T., & Dahlan, J.A. (2017). Using the 5E learning cycle with metacognitive technique to enhance students'mathematical critical thinking skills. *International Journal on Emerging Mathematics Education, 1*(1), 87-98. http://dx.doi.org/10.12928/ijeme.v1i1.5698.

INTRODUCTION

Various problems in life aspect occur in 21st century. To overcome this problem, critical thinking skills is needed. According to Chukwuyenum (2013), critical thinking had been used as one way to solve the problem in daily life because it involve logical reasoning, interpretation, analysis, and evaluate information so enable us to obtain valid and reliable decision. Based on his idea, someone who has critical thinking skills, will chose problem representation which is most suitable to help solving the problem,

Received January 24, 2017; Revised February 24, 2017; Accepted February 27, 2017

then choosing and using strategy to solve the problem which is backed by reason and proof. Therefore, problem solving and decision which are given will be backed by accurate reason or proof.

Critical thinking skills is high order thinking skills, in which the expert defined it in different way. One of them is Ennis (1996) who defined, "Critical thinking is reasonable and reflective thinking that is focused on deciding what to believe or do". Reflective means consider or thinking again everything faced before making decision. Reasonable means that all beliefs, views, or everything done which are backed by appropriate proof or reason.

Critical thinking is needed in various domains, included mathematics. According to Balcaen and Klassen (2007), critical thinking in mathematics is involvement of thinking through mathematical problem and make reasonable assessment about strategy, approach and solution. In accord with that opinion, Glazer (2001) explained that critical thinking in mathematics is ability and disposition to involve prior knowledge, mathematical reasoning, and cognitive strategy to generalize, prove or evaluate unfamiliar mathematical situation reflectively. Based on that definition, critical thinking in mathematics can be defined as ability to integrate prior knowledge, mathematical reasoning, and problem solving strategy to solve mathematical problem reflectively. Furthermore, according to Innabi (2003) critical thinking aspect related with learning material which comprise: concept, generalization, skill, algorithm and problem solving.

`The result of study shows that mathematical critical thinking skills (MCTS) development can enhance mathematics achievement (Jacob, 2012; Chukwuyenum, 2013). Similarly, critical thinking skills will encourage students to think independently and solve problem in school or in the context of everyday life (Jacob, 2012). Critical thinking is not limited to reflection, inference, and synthesis the information, enable individual to make reasonable assessment not only in class but in daily life (Beaumont, 2010). Thus, the critical thinking skills, which are developed through learning activities in the school, will be useful for solving various problems, whether the problems are directly related to learning activity or problems are in their daily lives. In other words, through the critical thinking skills, students will be able to consider or choose the important information that can be used to solve problems or to make a reasonable decision.

By viewing how important the development of critical thinking skills is, so that critical thinking development become curriculum agenda in the world, particularly in Indonesia. In Kurikulum Tingkat Satuan Pendidikan (KTSP) as stated in Permendiknas No.22 (2006) which is applied in Indonesia, it is implied that mathematics need to be given to students to equip them with logical, analytical, systematical, critical and creative thinking. Furthermore in 2013 curriculum as stated in Permendikbud No. 64 (2013), critical thinking is also stated in learning mathematics.

Even though critical thinking skills become one goal in learning particularly in mathematics, several result of study showed that this ability is still low. Hiebert (Lithner, 2008) reported that generally students still use thinking based on memorization than doing reasoning process in solving mathematical problem. The result of Trends in International Mathematics and Science Study (TIMSS) in 2007 and 2011 showed that average score of mathematics subject achievement in 2011 is in 38th rank from 42 participating countries. In TIMSS 2011 students are involved in various cognitive processes to solve the problem (Mullis, et al., 2012). Furthermore, Runisah

(2015) based on study toward 8th grade in Indramayu city, Indonesia concluded that students' mathematical critical thinking skills is still low.

One factor which affect the lack of students' mathematical critical thinking skills is learning process. In Indonesia, teaching practice focused on material content and ignore students' thinking ability development (Rohaeti, 2010). From inquiry result of Balitbang Depdiknas in 2007, implementation of learning in Indonesia generally still use lecture and ask and answer methods (Balitbang Depdiknas, 2007).

Activities can be done to enhance critical thinking skills in mathematics such as comparing, making conjecture, making induction, making generalization, making specialization, making classification, making deduction process, making visualization, ordering, making prediction, making validation, proving, analyzing, evaluating and making pattern, and determining functional relation among variables (Appelbaum, 1999). Futhermore, Beaumont (2010) stated that to enhance students' critical thinking skills, exercises in the form of task need to be given which require high reasoning to solve it such as task of observing, identifying assumption, challenging material to be understood, task of interpreting, task of discovering and investigating, task of analyzing and evaluating, and task of making decision. Therefore, to enhance mathematical critical thinking skills non routine tasks or problem need to be given which require high reasoning to solve it.

One of learning potentially to develop critical thinking skills is the 5E Learning Cycle with Metacognitive technique (LCM). The 5E Learning Cycle (LC) is developed by researcher team of Biological Science Curriculum Study leaded by Bybee. According to Bybee, et al. (2006) LC is influenced by Herbart psychology, John Dewey and Jean Piaget thinking. Piaget with his constructivism principle viewed that knowledge is not a set of fact, concept or rule which are ready to be transferred by teacher. Students should construct that knowledge and give meaning through various experiences in learning.

According to Bybee, et al. (2006), LC has five stages namely: engage, explore, explain, elaborate and evaluate. In engage stage, teacher access students' prior knowledge and help them to involve in new concept which encourage students interest to learn. In explore stage, students are involved in concept exploration activity to produce new ideas. In explain stage, students explain conceptual understanding or process skill which is obtained in earlier stage. In evaluate stage, assessment is done toward students' understanding and ability and give opportunity to teacher to evaluate students progress to achieve educational aim.

Those five stages can trigger students' critical thinking skill, because it involve prior knowledge, non routine situation, reasoning, cognitive strategy, and involve students in discussion to do exploration. This is in accord with Appelbaum (1999) and Beaumont (2010) argument that condition to critical thinking in mathematics beside should contain non routine situation, it should also use prior knowledge, reasoning, and cognitive strategy. Furthermore, according to Slavin (2011), critical thinking teaching which is effective depend on classroom determination that encourage different point of view acceptance and free discussion. Meanwhile, according to Ergin (Tuna & Kacar, 2013), LC involve high thinking order skill by stimulating students to explore. LC transmit critical thinking skill to students.

The 5E Learning Cycle with Metacognitive technique (LCM) is learning model that integrate directly Metacognitive technique in every stage of LC. Metacognition is a term introduced by Flavell in 1976. Flavell (Lioe et al., 2006) stated that metacognition is one's consciousness about his/her cognitive process and independency to achieve

the goal. One of Metacognitive technique is self-asking. In this study, question which is made focus on three categories which are adopted from Beeth (Mittlefehldt & Grotzer, 2003) namely intelligibility, wide-applicability, and plausibility. In first category that is intelligibility, the question asked is, "Am I able to understand the concept I learned?" In second category, that is wide-applicability, the question asked is, "What concept that can be used to solve this problem?" or, "Is the concept I learned can be used to solve the problem in another domain or in daily life?" In third category, that is plausibility, the question asked is: "Is problem solution I made can be reliable?".

From the above description, the use of LCM has potencies to develop students' critical thinking skills. However, the application of the model may not have the same effectiveness when it is applied to students who have different academic abilities. In other words, the use of LCM is probably more effective for a particular group rather than it is used in another group of students who have different academic abilities. This is in line with the opinion of Glazer (2001) as it is already described above that in critical thinking, reasoning, cognitive strategies, and the students' prior knowledge play an important role. Therefore, the analysis of the effect of the interaction between learning model and school level toward critical thinking skills is required. It is useful to determine the level of school where the model can be used more effectively, because the two level different schools have difference in a student's academic ability

There have been numerous studies on several approaches that is different from the 5E Leaning Cycle to enhance students' mathematical critical thinking skills (Rohaeti, 2010; Noer, 2010; Kurniati, Kusumah, Sabandar, & Herman, 2015; Yumiati, 2015; Firdaus, Kailani, Nor, & Bakry, 2015). Moreover some studies have been done on the use of the 5E Learning Cycle to enhance students' mathematical critical thinking skills (Erlian, 2009; Fatimah, 2012; Sofuroh, Masrukan, & Kartono, 2014; Kadarisma, 2015).

Meanwhile some studies on Metacognitive empowermen has been done (Schraw (Toit & Kotze, 2009); Camahalan, 2006; Ozcan & Erktin, 2015). However, only a bit studies on the use of the 5E Leaning Cycle with Metacognitive technique to enhance students'mathematical critical thinking skills. Therefore, the present study purposes at examining the use of the 5E Learning Cycle with Metacognitive technique to enhance mathematical critical thinking skills of junior high school students in one of cities in west Java, Indonesia.

This research was conducted in Indramayu west Java by considering the problem that is identified by the preliminary study. Preliminary study involved 33 junior high school students (Runisah, 2015) reported that the mean score of MCTS test of students is only 5.19 of the ideal maximum score of 16. This result shows that the critical thinking skills of students in mathematics were still low. Every question on the MCTS test was related to aspects of critical thinking with mathematical content, it includes concepts, generalization, and problem solving

RESEARCH METHOD

This study is a experimental with pretest-postest control group design (Ruseffendi, 2005) described as follows:

A O X_1 O
A O X_2 O
A O O

Information:
A : The selection of a random sample of classes at population
X_1: The application of The 5E Learning Cycle with Metacognitive technique (LCM)
X_2 : The application of The 5E Learning Cycle (LC)
O: Mathematical Critical Thinking Skills (MCTS) test (pretest-postest).

Population and Sample

Population in this study is junior high school students in Indramayu city, West Java Province, Indonesia. The sample is eighth grade students amounting to 173 students from two school level, classified as high amounting to 83 students and medium level amounting to 90 students. The selection of that school is done randomly from all Junior High Schools in Indramayu city. Three classes are selected randomly from each school level, one class are taught by LCM, one class are taught by LC, and one class are taught by CL. The determination of school level, based on accreditation score which is valid until the year 2016.

Instruments

Instrument used in this study consist of mathematical critical thinking skills (MCTS) test, Mathematical Prior Ability (MPA) test, and observation sheet. MCTS test consist of 10 items with ideal maximum score is 40. MCTS test is given to students before and after learning is implemented. MCTS test material is tailored with material given in the time of study, that is material of 8^{th} semester 1 is in accord with curriculum used. Before used, the experts consider MCTS test to fulfill face and content validity. Then try out test is done in limited scale. After being improved, instrument is tested in wide scale. Based on test result, it is obtained that test is valid and reliable with reliability coefficient r = 0.84 and according to Creswell (2012) it is in high category.

Meanwhile, material of MPA test was adjusted to the subject matter of Mathematics, which has been studied in the previous semester refered to the curriculum. Based on analysis, it is obtained that test is valid and reliable with reliability coefficient r = 0.83 for MPA test, with objective form and r = 0.64, for MPA with analytical test. MPA test is used for further convince that the MPA at the high school level is better than MPA at medium school level.

The magnitude of students' MCTS achievement is obtained from MCTS posttest score. The formulation developed by Meltzer (2002) is used to calculate the magnitude of enhancement. Whereas the calculation result of gain is interpreted by using classification of gain from Hake (1998).

RESULTS AND DISCUSSION

This part describes the result of the study and its discussion which is related to the relevant studies and theories.

The Enhancement of Students' MCTS

Base on normality test, data were not distributed normally. Therefore Kruskal-Wallis test is used to test mean difference of MCTS enhancement which is presented in Table 1.

Table 1. Summary of Mean Difference Test of MCTS Enhancement

School Level	Group	$\langle g \rangle$	Chi-Square	*Sig*.	Ho
High	LCM; LC; CL	0.68; 0.53; 0.38	30.21	0.000	rejected
Medium	LCM; LC; CL	0.57; 0.46; 0.30	35.07	0.000	rejected
Total	LCM; LC; CL	0.62; 0.49; 0.34	57.37	0.000	rejected

LCM : The 5E Learning Cycle with Metacognitive Technique
LC : The 5E Learning Cycle
CL : Conventional Learning.

Based on Table 1, it is found out that probability (significance) value is less than significance degree $\alpha = 0.05$, thus H_0 is rejected. Thus in terms of overall and for each school level, it means that at least there is one group who has mean gain which is different from another group. Further, based on Multiple Comparison Between Treatments test at significance degree $\alpha = 0.05$, in terms of overall and in high school level, MCTS enhancement of students who are taught by LCM is better than students who are taught by LC and students who are taught by CL. MCTS enhancement of students who are taught by LC is better than students who are taught by CL. In medium school level, there is no difference of MCTS enhancement between students who are taught by LCM and students who are taught by LC. However, MCTS enhancement of students who are taught by LCM and students who are taught LC is better than students who are taught by CL.

Interaction Effect between Learning Model and School Level toward Students' MCTS Enhancement

The Adjusted Rank Transform test (Leys and Schumann, 2010) is done to find out interaction effect between learning model and school level toward students' MCTS enhancement. From the calculations, the value of F = 1.20 with a probability value 0.304. Thus, it can be concluded that there is no interaction effect between learning model and school level toward students' MCTS enhancement.

The Achievement of Students' MCTS

The achievement of students' MCTS is determined based on posttest score. Further, percentage of students' MCTS achievement can be seen in Figure 1.

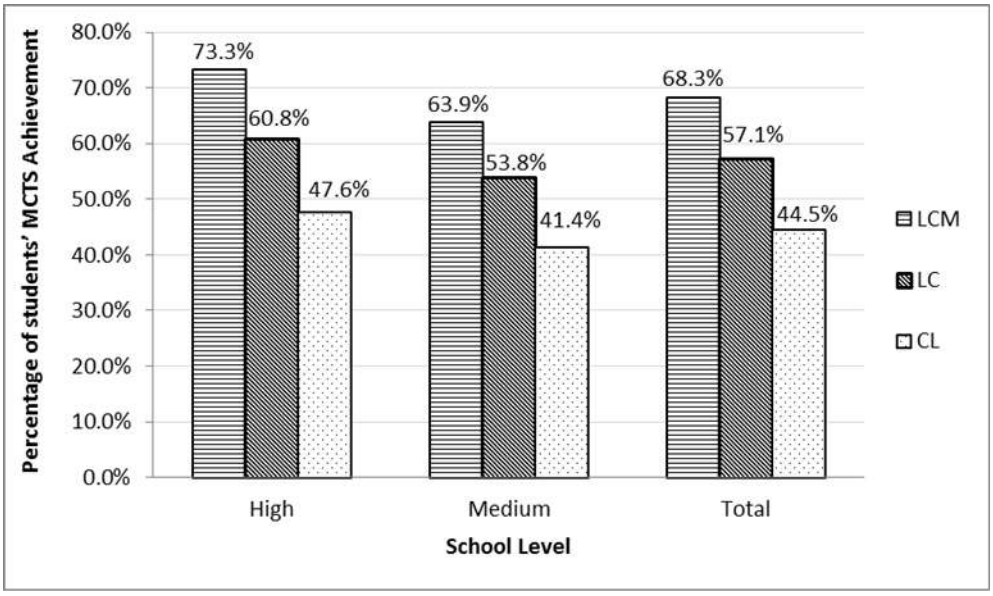

Figure 1. The Achievement of Students' MCTS

From Figure 1, it can be found out that in terms of overall and for all school levels, MCTS achievement of LCM group is higher than LC group and CL group, MCTS achievement of LC group is higher than CL group.

Further, based on normality test, data were not distributed normally. Therefore Kruskal Wallis test is used to test mean difference of MCTS achievement which is presented on Table 2.

Table 2. Summary of Mean Difference Test of MCTS Achievement

School Level	Group	Posttest	Chi-Square	Sig.
High	LCM; LC; CL	29.31; 24.30; 19.03	24,59	0.000
Medium	LCM; LC; CL	25.57; 21.20; 16.57	24.29	0.000
Total	LCM; LC; CL	27.30; 22.84; 17.80	44.01	0.000

LCM : The 5E Learning Cycle with Metacognitive Technique
LC : The 5E Learning Cycle
CL : Conventional Learning.

Based on Table 2, it is found out that probability (significance) value is less than significance degree $\alpha = 0.05$, thus H_0 is rejected. Thus in terms of overall and for each school level, it means that at least, there is one group who has mean gain which is different from another group. Further, based on Multiple Comparison Between Treatments test at significance degree $\alpha = 0.05$, in terms of overall and from high and medium school level, MCTS achievement of students who are taught by LCM is better than students who are taught by LC and students who are taught CL. MCTS achievement of students who are taught by LC is better than students who are taught by CL

Interaction Effect between Learning Model and School Level toward Students' MCTS Achievement

The Adjusted Rank Transform test (Leys and Schumann, 2010) is done to find out interaction effect between learning model and school level toward students' MCTS achievement. From the calculations, the value of F = 0.421 with a probability value 0.667. Thus, it can be concluded that there is no interaction effect between learning model and school level toward students' MCTS achievement.

In terms of overall, MCTS enhancement of students who are taught by LCM is 0.62, whereas students who are taught by LC is 0.49 and students who are taught by CL is 0.34. That enhancement is in medium category based on classification of Hake. MCTS enhancement of students is supported by its achievement. MCTS achievement of students who are taught by LCM is 27.30 or 68.3% from ideal maximal score. MCTS achievement of students who are taught by LC is 22.84 or 57.1% from ideal maximal score. Meanwhile, MCTS achievement of students who are taught by CL is 17.80 or 44.5% from ideal maximal score. Furthermore, based on statistic test result MCTS enhancement and achievement of students who are taught by LCM is better than students who are taught by LC and students who are taught by CL. MCTS enhancement and achievement of students who are taught by LC is better than students who are taught by CL.

Based on statistic test result, the result obtained in terms of overall and students from high school level has similarity namely MCTS enhancement and achievement of students who are taught by LCM is better than students who are taught by LC and students who are taught by CL. MCTS enhancement and achievement of students who are taught by LC is better than students who are taught by CL.

In medium school level, it is concluded that there is no difference of MCTS enhancement between students who are taught by LCM and students who are taught LC in significance degree of 0.05. Nevertheless, MCTS achievement of students who are taught by LCM is higher than students who are taught by LC, MCTS enhancement of students who are taught by LCM is 0.57 and for students who are taught by LC is 0.46. Meanwhile, MCTS enhancement of students who are taught by LCM and students who are taught by LC is better than students who are taught by CL. Futhermore, MCTS achievement of students who are taught by LCM is better than students who are taught by LC and students who are taught by CL. MCTS achievement of students who are taught by LC is better than students who are taught by CL.

In general, the result of study show that LCM is better in facilitating students to develop MCTS than LC and CL, and LC is better in facilitating students to develop MCTS than CL. This is possible because in LC students are involved in learning activity actively through discussion to do activities such as comparing, making conjecture, making generalization, making prediction, making validation, analyzing, evaluating, and determining functional relation among variables. Those activities will develop students' mathematical critical thinking skills. It is proven what has been stated by several expert (Appelbaum, 1999; Beaumont, 2010; Glazer, 2004). In line with it, according to Slavin (2011) the effective teaching of critical thinking depend on determination of classroom which encourage the acceptance of different point of view and free discussion. Furthermore, Ergin (2012) added that the 5E model is the most effective way to involve students in learning. Students involvement in learning will develop their thinking ability among other critical thinking skills.

In LC, students are involved in exploration activity toward concept learned, thus students understanding will become deeper. According to Carpenter (Franke & Kazemi, 2001), when individuals learn with understanding, they can use the knowledge to solve new problems. Meanwhile, in CL, teaching and learning activity is more teacher centered. In CL, teacher give concept which is learned directly, students just receive what is delivered by teacher, then students are given problem exercises. Therefore, in CL learning is dominated by teacher. Thus in CL development of critical thinking skills is lacking.

In LCM, besides having strengths contained in LC, students' metacognition is more empowered compared to LC and CL. Students' metacognition empowerment is done by guiding student to ask themselves and answer it. Therefore, students will try to realize their thinking process. They will think about their experience toward concept, another domain or relation among concepts. This is strongly support development of critical thinking skills that which will be used in solving the problem. This is in accord with Panaoura and Phillippou (2005) that if someone not aware of his/her process and cognitive ability, we will not be able to improve his/her performance. Furthermore, Schraw and Dennison (Panaoura & Philippou, 2005) concluded that students who are skillful in assessing their Metacognitive and aware of their ability to think are better than students who not aware of their mental system mechanism in solving mathematical problem.

This study result is in accord with study result of several expert that the use of the 5E Learning Cycle support students' critical thinking skills in mathematics (Erlian, 2009; Fatimah, 2012; Sofuroh, Masrukan, & Kartono, 2014). Other than, study result of several expert showed that there is positive influence from constructivism based learning toward enhancement of students' mathematical critical thinking skills (Rohaeti, 2010; Noer, 2010; Kurniati, Kusumah, Sabandar, & Herman, 2015; Yumiati, 2015; Firdaus, et al. , 2015).

This study also show that school level factor has significant effect toward achievement and enhancement of students' MCTS. For each learning model, students in high school level obtain achievement and enhancement of MCTS which is higher than students in medium school level. In other word, students in high school level get more advantage in achievement and enhancement of MCTS than students in medium school level. This occurs because Mathematical Prior Ability (MPA) of students at the high school level is better than MPA of students at medium school Level. MPA of students is one aspect that support the critical thinking skills in mathematics. This is in line with the opinion of Glazer (2001) that the critical thinking in math involves prior knowledge of the students.

This study also find that there is no interaction effect between learning model and school level toward enhancement and achievement of students' MCTS. This is possible because in one class, each discussion group has relatively the same academic ability. Each group consists of students who have the academic ability of high, medium, and low. This condition causes the application of LCM and LC run smoothly on the high school level as well as at the medium school level. Therefore, LCM and LC can be used in medium and high level school, because in whichever level, MCTS enhancement and achievement of students who are taught by LCM will be higher than students who are taught by LC and CL. MCTS enhancement and achievement of students who are taught by LC will be higher than students who are taught by CL.

CONCLUSION

Based on result study, it can be concluded that in terms of overall and in high school level, MCTS enhancement and achievement of students who are taught by LCM is better than students who are taught by LC and students who are taught by CL. MCTS enhancement and achievement of students who are taught by LC is better than students who are taught by CL. In medium school level, there is no difference of MCTS enhancement between students who are taught by LCM and LC, however MCTS enhancement of students who are taught by LCM and students who are taught by LC is better than students who are taught by CL. Whereas, MCTS achievement of students who are taught by LCM is better than students who are taught by LC and students who are taught by CL. MCTS achievement of students who are taught by LC is better than students who are taught by CL.

In terms of overall and students in high school level, MCTS enhancement of students who are taught by LCM, LC, and CL is in medium category. In medium school level, MCTS enhancement of students who are taught by LCM and LC is in medium category, but MCTS enhancement of students who are taught by CL is in low category. Thus the application of LCM and LC has not yet gave maximal effect toward students' MCTS enhancement. Therefore, further research is needed to examine its cause.

There is no interaction effect between learning model and school level toward enhancement and achievement of students' MCTS. Thus, LCM and LC can be used for high school level and medium school level to enhance students' MCTS.

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