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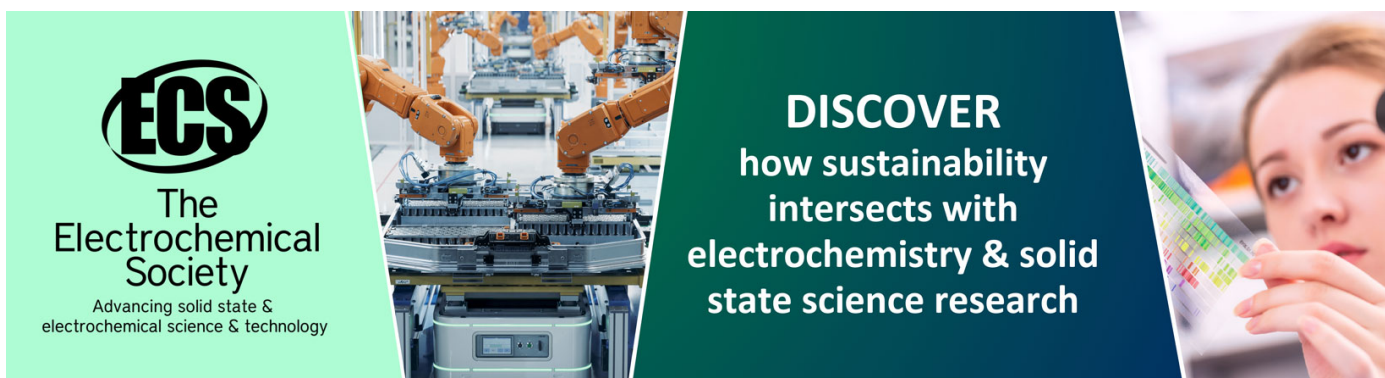
## The effect of 5E learning cycle with metacognitive techniques and mathematical prior ability on mathematical creative thinking skills

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# The effect of 5E learning cycle with metacognitive techniques and mathematical prior ability on mathematical creative thinking skills

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**Abstract.** The purpose of this study is to investigate the role of the 5E Learning Cycle with Metacognitive Techniques (LCM) and Mathematical Prior Ability (MPA) on Mathematical Creative Thinking Skills (MCTS). The subject of the study was 173 eighth grade students from high level school and medium level school in Indramayu, Indonesia. This study used the quasi-experimental method with a pretest-posttest control group design. At each school level, three classes were used in this study, one class used the 5E Learning Cycle with Metacognitive Techniques (LCM), and the other class used the 5E Learning Cycle (LC) and Conventional Learning (CL). The students were classified into three levels based on Mathematical Prior Ability (high, medium, and low). The instruments used are MPA test and MCTS test. The study reveals that in terms of overall and in every MPA level, LCM gives better influence on students' MCTS than LC and CL, LC gives better influence on students' MCTS than CL. There is an interaction effect between the learning model and MPA level toward the enhancement of students' MCTS.

## 1. Introduction

Creative thinking skill is a way of thinking that leads to the generated new ideas or ways of solving problems. In a more detailed way, according to Guilford as cite by Starko [1], components of divergent thinking including fluency (ability to build many ideas), flexibility (ability to build various types of ideas from different viewpoints), Originality (ability to build uncommon ideas), and elaboration (ability to develop ideas). Another importance aspect in creative thinking is sensitivity on problems. Meanwhile, in mathematics, Haylock, Jensen, & Kim, Cho as cited in Mann [2] have applied the concept of fluency, flexibility, and originality on the concept of creativity. Holland in Imai [3] added elaboration and sensitivity on the concept of creativity in mathematics. Thus creative thinking skills in mathematics dealing with the ability to solve problems using the new idea. Creative thinking skills in mathematics characterized by sensitivity, fluency, elaboration, flexibility, and originality.

In students' problem solving, mathematical creative thinking plays an important role mathematically [4]. Although creative thinking skills need to be developed, in fact, the creative thinking skills of students is still low. This is based on results of the PISA study in the year 2015 with a score of 386, in the field of mathematical competence, there was an increase compared to 2012 with a score of 375. The achievement level was still below the average. In addition, based on the results of the TIMSS study in 2015, according to Rahmawati [5], the high order thinking skills of Indonesian students still needs to be developed. One of high order thinking skills is creative thinking.



Learning model is one of the factors that influence students' creative thinking skills. One of learning model potential to develop creative thinking skills is the 5E Learning Cycle with metacognitive techniques (LCM). LCM is a learning model that integrate metacognitive techniques into Learning Cycle 5E (LC) [6]. Engage, explore, explain, elaborate, and evaluate are the stages in LC. At the stage of engaging, the teachers access the students' prior knowledge and help them engage in new concepts that encourage their learning interest [7]. In the stage of exploring, the students explore the concepts or the materials they have learned to generate new ideas. In the stage of explaining, the process skills obtained in the stage of exploring were explained by students. Further the concept, process, or skill is directly explained by the teacher. In the stage of elaborating, the concepts that have been obtained by students are applied to broaden students' understanding. Further in the stage of evaluating, students' understanding and abilities of the concepts or material they have learned are evaluated by the teacher.

Metacognition is 'one's knowledge concerning one's own cognitive processes and products or anything related to them [8]. Meanwhile, metacognitive techniques are integrated into LCM. is self-asking with questions adapted from Beeth as explained by Runisah et al. [6] namely intelligibility, wide applicability, and plausibility. The intelligibility category is related to the questions intended to understand students' conceptual understanding. The wide-applicability category is related to the questions about students' knowledge of the application of a concept. The plausibility category, is related to the questions about the logic of ideas that students give.

Another factor that influences students' mathematical creative thinking skills is the Mathematical Prior ability (MPA). The students must be able to master the main concepts related to the topics so that they can think creatively in solving the problems they face [5]. To master the next mathematics contents and the more complex mathematics processes is needed comprehending MPA well [9].

Various studies to enhance students' mathematical creativity have been done such as by [4, 5, 10-12]. These studies use various learning models that are different from LC. Further, studies of the implementation of LC have been frequently done [13-15]. However, only a bit of study on the use of the 5E Learning Cycle to enhance mathematical creativity. Therefore, it is considered necessary to conduct a research to know the effect of the implementation of LCM and MPA on mathematical creative thinking skills.

Therefore, this study aims to review the enhancement of MCTS between the students who received LCM and the students who received LC and CL, both observed overall and based on MPA level. Furthermore, this research aims also to examine whether there is any interaction effect between the learning model and MPA level to the enhancement of MCTS.

## 2. Method

This study used a quasi-experimental method with a pretest-posttest control group design. The population of the research is junior high School students in Indramayu City, West Java Province, Indonesia. The sample is eighth-grade students amounting to 173 students, 83 students from the high level school and 90 students from the medium level school. Three classes were randomly selected from all of the eighth-grade students in high level and medium level school, one class was thought with LCM, another one class was thought with LC, and the other class was thought with conventional Learning (CL). The school level is based on the level of school determined by the education office in Indramayu

The instruments used in this research were the MCTS and MPA test. In this study, the evaluation of MCTS used sensitivity, fluency, flexibility, elaborate, and originality aspect. These components associated with the material being taught. MCTS test was valid and reliable with reliability coefficient  $r = 0,902$ . Meanwhile, the material of the MPA test was adjusted to the subject matter of Mathematics, which has been studied in the previous semester. That test was valid and reliable with reliability coefficient  $r = 0.83$  for MPA test with objective form and  $r = 0.64$ , for MPA with the analytical test.

The achievement of students' MCTS determined based on posttest scores. Meanwhile, to calculate the magnitude of the enhancement of students' MCTS is calculated using the formula of normalized gain developed by [16]. The gain calculation results were interpreted by using the classification Gain

of [17]. Further, criteria for high level if  $x \geq \bar{x} + s$ , medium level if  $\bar{x} - s \leq x < \bar{x} + s$ , and low level if  $x < \bar{x} - s$  ( $s$ : standard deviation,  $x$ : MPA score).

Meanwhile, the activities carried out in each phase of the LCM are presented in Table 1.

**Table 1.** Description of learning activities using LCM

| Stage     | Learning activities                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Engage    | 1) The teacher gives a problem related to the material to be learned to access students' prior ability and help them engage in new concepts to be learned. 2) The teacher gives an opportunity for students to ask themselves. "What concept that can be used to solve this problem? ". The teacher holds a question and answers with students regarding the question.                                                              |
| Explore   | 1) Students carry out activities such as, test predictions, build models to look for possibilities, interpret, try other alternatives, or explore concepts that are being studied through group discussions, Teachers as facilitators. 2) The teacher gives the opportunity for students to ask themselves, " Should I really believe this idea? Next, the teacher holds a question and answer with students regarding the question |
| Explain   | 1) The teacher provides opportunities for students to explain the results of their exploration. 2) The teacher directly introduces concepts, processes, or skills while clarifying the students' explanations. 3) Students are given the opportunity to ask themselves, " Am I able to understand the concept I learned?" Next, the Teacher held a question and answer session with students regarding the question.                |
| Elaborate | 1) The teacher expand students' conceptual understanding, by giving practice questions 2) Students are given the opportunity to ask themselves . " Is the concept I learned can be used to solve the problem in another domain or in daily life?" Next, the teacher holds a question and answer with students regarding the question.                                                                                               |
| Evaluate  | The teacher gives a test to evaluate the extent to which students have mastered the concept.                                                                                                                                                                                                                                                                                                                                        |

Table 1 shows learning activities in LCM. LCM and LC models are only different when using the metacognitive techniques that is when students are given the opportunity to ask themselves questions followed by discussion.

### 3. Result and Discussion

#### 3.1. Recapitulation of pretest, posttest, and n gain of Mathematical Creative Thinking Skills (MCTS)

Description of MCTS of students are presented in Table 2.

**Table 2.** Recapitulation of Pretest, posttest, and n Gain  $\langle g \rangle$  of MCTS

| Level of MPA | Stat      | Model    |          |                     |    |         |          |                     |    |         |          |                     |    | Total   |          |                     |     |
|--------------|-----------|----------|----------|---------------------|----|---------|----------|---------------------|----|---------|----------|---------------------|----|---------|----------|---------------------|-----|
|              |           | LCM      |          |                     |    | LC      |          |                     |    | CL      |          |                     |    |         |          |                     |     |
|              |           | .Pretest | Posttest | $\langle g \rangle$ | N  | Pretest | Posttest | $\langle g \rangle$ | N  | Pretest | Posttest | $\langle g \rangle$ | N  | Pretest | Posttest | $\langle g \rangle$ | N   |
| High         | $\bar{X}$ | 12,64    | 50,36    | 0,87                | 11 | 11,82   | 46,55    | 0,79                | 11 | 11,50   | 40,83    | 0,66                | 12 | 11,97   | 45,76    | 0,77                | 34  |
|              | S         | 0,92     | 1,80     | 0,04                |    | 1,60    | 2,34     | 0,05                |    | 1,38    | 4,73     | 0,10                |    | 1,38    | 5,12     | 0,11                |     |
| Medium       | $\bar{X}$ | 8,64     | 42,97    | 0,73                | 33 | 8,11    | 35,41    | 0,57                | 34 | 8,30    | 25,59    | 0,37                | 37 | 8,35    | 34,32    | 0,55                | 104 |
|              | S         | 1,76     | 6,30     | 0,12                |    | 1,49    | 7,09     | 0,14                |    | 1,66    | 6,59     | 0,13                |    | 1,64    | 9,76     | 0,20                |     |
| Low          | $\bar{X}$ | 5,42     | 27,75    | 0,44                | 12 | 4,92    | 20,17    | 0,30                | 12 | 5,09    | 15,73    | 0,21                | 11 | 5,14    | 21,37    | 0,32                | 35  |
|              | S         | 0,51     | 3,79     | 0,73                |    | 0,79    | 3,97     | 0,72                |    | 0,30    | 1,90     | 0,04                |    | 0,60    | 6,00     | 0,11                |     |

|       |           |      |       |      |    |      |       |      |    |      |       |      |    |      |       |      |     |
|-------|-----------|------|-------|------|----|------|-------|------|----|------|-------|------|----|------|-------|------|-----|
| Total | $\bar{X}$ | 8,73 | 41,16 | 0,70 | 56 | 8,16 | 34,35 | 0,56 | 57 | 8,35 | 26,83 | 0,40 | 60 | 8,41 | 33,95 | 0,55 | 173 |
|       | $S$       | 2,73 | 9,20  | 0,18 |    | 2,60 | 10,33 | 0,19 |    | 2,46 | 9,75  | 0,18 |    | 2,59 | 11,36 | 0,22 |     |

$N$  : The number of students

$S$  : standard deviation

$\bar{X}$  : Mean

The maximal ideal of MCTS test score : 56

Base on Table 2, the achievement and enhancement of students MCTS who received LCM were higher than students who received LC and CL, students who received LC were greater than students who received CL. Thus descriptively, LCM has a greater influence in determining achievement and enhancement of students' creative thinking skills than LC and CL. When viewed from the MPA, students with high-level MPA have higher average achievement and enhancement in MCTS compared to students in the medium MPA level. Students with a medium level of MPA are having greater achievement and enhancement in MCTS than low-level students. Thus the MPA level has an influence on students' MCTS.

### 3.2. The Enhancement of Students' Mathematical Creative Thinking Skills (MCTS)

Based on normality test results, therefore Kruskal-Wallis test and one-way ANOVA were conducted to test the mean difference of MCTS enhancement. Summary of the test result is presented in Table 3.

**Table 3** Summary of the Test of Students MCTS Enhancement

| MPA Level | Learning Model | N Gain           | $F$   | Chi-Square | Sig.  |
|-----------|----------------|------------------|-------|------------|-------|
| High      | LCM; LC; CL    | 0.87; 0.79; 0.66 | 26.39 | -          | 0.000 |
| Medium    | LCM; LC; CL    | 0.73; 0.57; 0.37 | -     | 60.91      | 0.000 |
| Low       | LCM; LC; CL    | 0.44; 0.30; 0.21 | 39.62 | -          | 0.000 |
| Total     | LCM; LC; CL    | 0.70; 0.56; 0.40 | -     | 55.24      | 0.000 |

LCM: The 5E Learning Cycle with Metacognitive Techniques.

LC: The 5E Learning Cycle

CL: Conventional Learning

Table 3 shows that in terms of overall students and in every MPA level, that at least there is one group who has a mean enhancement which is different from another group. Furthermore, from the post hoc test concluded, in terms of overall students and in every MPA level, MCTS enhancement of students who received LCM is better than students who received LC and students who received CL. MCTS enhancement of students who received LC is better than students who received CL.

### 3.3. Interaction Effect between Learning Model and MPA toward Students' MCTS Enhancement

The Adjusted Rank Transform Test is done to find out the interaction effect between the learning model and MPA toward students' MCTS enhancement [18]. This is because the normality of the distribution is not fulfilled. From the calculations, the value of  $F = 4.251$  with a probability value of 0.003. Thus, it can be concluded that there is an interaction effect between the learning model (LCM, LC, CL) and MPA (high, medium, low) toward students' MCTS enhancement.

### 3.4. Discussion

Based on the explanation in section 3.2, the use of LCM is more influential toward students' MCTS enhancement than LC and CL. LC is more influential toward students' MCTS enhancement than CL. This is possible because, the LC model involves students to analyze, construct conjectures, solve problems, determine solutions that are different from the examples given by the teacher, and explore

to find formulas. Those activities will develop students' MCTS [12, 19] Furthermore, the teacher needs to enable creative exploration and reward students who seek to expand their content to develop mathematical creativity [2].

LC is learning model that encourages students to learn the meaning of the concept, which is being studied without the teacher's help. Students conduct an exploration of the concept by using their own ideas taken from various viewpoints. Therefore, LC creates creative learning.

Additionally, to perform the creative process, there are five stages namely stimulus, exploration, planning, activity, and review [20]. By heeding to the process, the use of the LC model encourages students to do a creative process. This is because those five stages are on the LC stage.

On LCM, other than various advantages possessed by LC, another advantage is the use of metacognitive techniques, which is directly guided by teachers so that it helps students to empower their metacognitive. Metacognitive awareness variables have a direct contribution to cognitive variables that are the influence of factors outside the metacognitive awareness variable [21]. Further, based on the results of the study concluded that learning enriched with metacognitive activities can increase student learning achievement [22-24]. Various advantages of the LCM and LC are not on CL. Differences as a result of using LCM with CL can be seen in Figure 1.

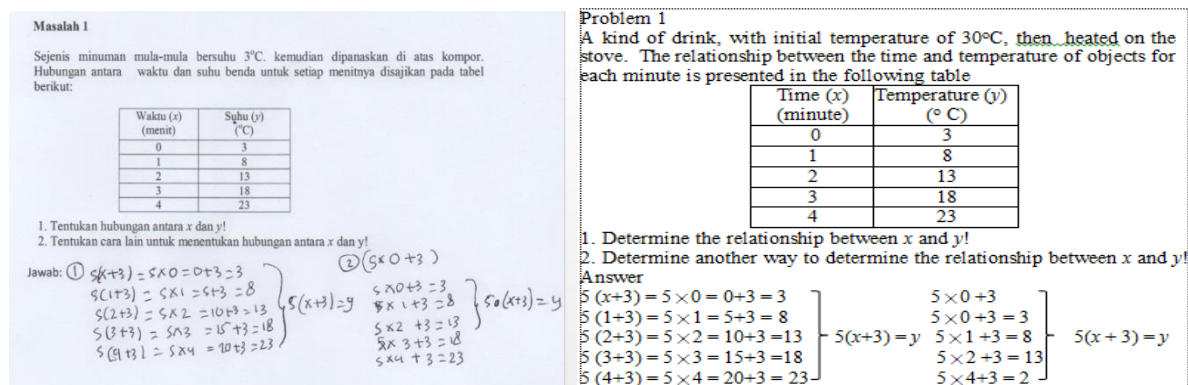


**Figure1.** Activities of students using LCM (Left), activities of students using CL (right)

Figure 1 shows that students who study with the LCM model are more active in learning than students who use CL. It is because, on CL a teacher directly gives the concept or the material through lecturing, and then he distributes exercises to students. Students are not given the opportunity to think creatively in obtaining or finding concepts learned.

This finding is consistent with the previous one that learning by using LC models is effective in improving mathematical creativity [25]. This study is also consistent with other studies that constructivism-based learning will enhance students' mathematical creative thinking skills [4,5,11,12].

Another finding of this study is that the MPA along with the learning model takes effect on the enhancement of creative thinking skills. It is based on study results, that there is an interaction effect between the learning model and the MPA level towards the enhancement of creative thinking skills. The presence of interaction effect between MPA and learning model is enabled due to the fact that student's with high MPA level have better abilities to perform various activities in LCM to spur the increase of students' creative thinking skills. On LCM, it requires students' ability to explore, elaborate, explain, and empower their metacognitive to assist them in learning activities. Meanwhile, lower MPA level students, still generally feel difficult in performing those activities. This is reflected in ongoing learning activities. For example, there are difficulties obtained by students with a low level MPA when they are working on the given problems in the engage stage in Figure 2.



**Figure 2** Problems in engage stage and example answer with translation

To solve the problem no. 1, the student is expected to try to solve it with their prior knowledge about how to determine the formula of the function. The problem no. 2 is related to the material that will be learned, namely the equation of the line passing through points  $(x_1, y_1)$  and  $(x_2, y_2)$ . The second question is intended to arouse students' interest in learning the material.

Figure 2 shows the difficulties for low level students in answering the problems given to them. Meanwhile, because the question is related to the previous material students have learned, students who have medium and high MPA levels can answer question number 1. The errors made by students are related to multiplication of algebraic expressions material which is the initial material that they should have mastered. The errors are seen in answer no. 1 and 2. For number 1, student answered with the same pattern as example  $5(1+3) = 5 \times 1 = 5+3 = 8$  and  $5(2+3) = 5 \times 2 = 10+3 = 13$  which was the wrong answer. In this case, student do not understand the distributive property of multiplication over addition. In the answer number 2 it can be seen that student made wrong generalization, even though the process he has done leads to the correct answer, he concluded that  $y = 5(x+3)$ . In this case they argued that  $5(x+3) = 5x+3$ .

In low MPA students, the use of LCM and LC models do not offer a large impact on the enhancement of creative thinking skills, because it only achieved an increase of 0.30 for students who acquired LC and 0.44 for students who acquired LCM. Both values are only slightly different with an increase obtained through the use of the CL model, which equals to 0.21.

#### 4. Conclusion

In terms of overall students and from all school's MPA level, MCTS enhancement of students who received LCM are better than students who received LC and students who received CL. MCTS enhancement of students who received LC is better than students who received CL. Furthermore, MCTS enhancement of students who received LCM is 0.70. It is at a high level. Meanwhile, MCTS enhancement of students who received LC is 0.56 and students who received CL is 0.40, that enhancement is in medium level. Lastly, there is an interaction effect between the learning model and MPA toward the enhancement of students' MCTS. In low MPA students, the use of LCM and LC models do not offer a large impact on the enhancement of MCTS. Thus other studies are needed to determine the reason for it.

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