The Emergence of Metacognitive Activities Through the Scaffolding Interaction

Nophem Kusumaningtyas Sumitro, Cholis Sa'dijah, Swasono Raharjo, Rustanto Rahardi

Abstract: ***This research aims to describe the scaffolding interaction which can promote metacognitive activities in the mathematical problem-solving process. The type of this research is qualitative descriptive research. The subject in this research was a junior high school student. The subject was chosen because there were no metacognitive activities on the problem-solving process given by the researchers prior to this research. The research was conducted for six consecutive days. In this research, the subject worked on four mathematical problems using the thinking aloud method. The researchers gave scaffolding interactions on the second to the fourth day, but not on the first, the fifth, and the sixth day. The results showed that on the first day, the subject could not solve the problem and the subject's metacognitive activities did not appear. On the second to the fourth day, the researchers provided scaffolding interactions in accordance with the problems faced by the subject. The researchers provided scaffolding interactions of explaining, reviewing, and restructuring based on the subject's problems. On the fifth to the sixth day, the subject was not only able to solve mathematical problems, but also showed metacognitive activities of awareness, evaluation, and regulation***

Keyword: Metacognition, Problem-Solving, Scaffolding.

I. INTRODUCTION

Metacognition is the students' ability and knowledge in regulating their cognition [1]. This ability is important in all mathematical performance, including in the problem-solving process [2],[3],[4],[5],[6],[7],[8]. It is in line with [9], [10] opinion that metacognition is important for knowing one's thinking process in problem-solving. Several researchers have conducted researches on metacognition in relation to problem-solving. The researches include metacognition and its effectiveness, metacognition related to learning strategies, and metacognition in relation to learning evaluation.

Researches on metacognition and its effectiveness were conducted by [8],[2],[11],[1],[7], and [12]. The research results showed that metacognitive experiences are important for students because when students know how to apply metacognitive experiences, there is a possibility that problem-solving will be successful. Researches on metacognition related to learning strategies were conducted by [8],[4],[13],[10],[14] and [15]. Their research concluded that effective behaviors, such as perseverance, persistence, confidence, interest, and frustration, often occur during problem-solving activities, causing continuous interplay of cognitive and metacognitive behaviors and strategies appear to be necessary for successful problem-solving. Researches on metacognition in relation to learning evaluation were conducted by [16], [17], [7] and [18]. The results showed that metacognition can increase metacognitive awareness and develop a positive attitude towards learning.

However, the facts in the field reveal that many students do not show their metacognitive activities in the problem-solving process. It can be seen from the data taken by the researchers in some seventh-grade students. From data of 20 students, 18 students did not show their metacognitive activities in the process of solving the mathematical problem given by the researchers. The researchers referred to metacognitive activities based on [11], [4] research. They stated that when individuals conduct metacognition, individuals do three important components, i.e. awareness, evaluation, and regulation [11], [4]. Awareness refers to a situation in which individuals are aware of their own thinking. This situation shows individuals' knowledge about what they know (tasks, specific knowledge, relevant mathematical knowledge, or problem-solving strategies), where the individuals' position in the problem-solving process and what is needed to do or what can be done. Evaluation is a situation in which individuals evaluate the decision-making process in performing mathematical thinking activities which indicate individuals evaluate their thinking effectiveness and limitations, the chosen strategy effectiveness, assessment of the results, assessment of problem difficulties, and assessment of the progress, ability, or understanding. Regulation is a situation in which individuals think about planning strategy, setting goals, and choosing a problem-solving strategy.

One alternative to stimulate student metacognition is the provision of scaffolding. [19], [20] ask that the use of metacognitive scaffolding to improve college students' academic success. Scaffolding is a form of temporary structured guidance for students to make them become independent, self-regulating, and problem solvers [21], [22], [23]. Scaffolding is temporary, meaning that if the students' ability has developed, scaffolding will gradually be reduced along with the increased students'ability to complete their tasks independently.

According to [24], there are three interactions in scaffolding, i.e.: level 1, level 2, and level 3. Level 1 is environmental provisions as the most basic level in scaffolding. At this level, the appropriateness of the learning environment in the classroom can support learning. This level can take place without the intervention of the teacher.

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Nophem Kusumaningtyas Sumitro, Mathematrics Education, Universitas Negeri Malang, East Java, Indonesia.

Cholis Sa'dijah, Mathematrics Education, Universitas Negeri Malang, East Java, Indonesia.

Swasono Raharjo, Mathematrics Education, Universitas Negeri Malang, East Java, Indonesia.

Rustanto Rahardi, Mathematrics Education, Universitas Negeri Malang, East Java, Indonesia.

One example is seating arrangements or group settings. Level 2 is known as explaining, reviewing, and restructuring. At this level, the teacher helps the students to reach their understanding. In this case, the teacher gives an explanation, a review, and the understanding reinforcement to the students. Level 3 is conceptual development, which is developing the concept mastered by the students or constructing relationships between concepts.

The interactions proposed by [24], [25] are included in the scaffolding stage called contingency. [21] stated that the scaffolding interaction process involves three key characteristics, i.e. contingency, fading, and transfer of responsibility. In the scaffolding process, the applied scaffolding involves the three characteristics above. The contingency stage adopts interactions proposed by [24]. Scaffolding requires suitability between problems in the task with the provided support so that individuals can process information in their working memory effectively [26], [27] stated that there are three factors need to be considered in preparing to scaffold, i.e. determining the tasks in the students'Zone of Proximal Development (ZPD), anticipating obstacles that may be found in the completion of tasks, and preparing to scaffold in accordance with these obstacles. From these reviews, the researchers aim to identify the scaffolding interaction which can promote metacognitive activities in the mathematical problem-solving process.

II. METHOD

The type of this research is a qualitative descriptive research in which the researches describe the scaffolding interaction which can promote metacognitive activities in the mathematical problem-solving process. It is in line with [28] statement that the purpose of qualitative descriptive research is to describe, analyze, diagnose, and present the situation of an individual or group.

The research was conducted in one of the junior high schools in a small city. The research subject was one of the seventh-grade students in the school. The subject was chosen because there were no metacognitive activities on the problem-solving process given by the researcher prior to this research. The research was conducted for six consecutive days. For six days, the researchers gave an assessment in the form of four essay questions to the subject. According to [29], assessment is a systematic process of gathering information without referring to a decision about the value. The mathematical problems were in accordance with the material already taught to the subject. Mathematical problems given by the researchers are the following:

1. You want to buy refreshments for your party in various packages; 500 ml which cost Rp. 2,500.00; 1 liter which cost Rp. 4,250.00; 1.5 liters which cost Rp. 6,000.00. You know that 1 liter = 1000 ml. In your party, you need 6 liters of refreshments. Which package is the cheapest for your party?"(The problem was adopted from the mathematical problem [14].
2. "Someone bought a 90 m2house for Rp. 150,000.00/meter. He paid off the price in advance and the rest in 25 monthly installments. Which was the price of each installment?"
3. Which are the possibilities to form a triangle if there are long sticks provided in the following size? Investigate! a. 11 cm, 12 cm, and 15 cm; b. 2 cm, 3 cm, and 6 cm; c. 6 cm, 10 cm, and 13 cm; d. 5 cm, 10 cm, and 15 cm
4. Given four triangles (arbitrary triangle, right triangle, equilateral triangle, an isosceles triangle) having the same circumference of 24 cm. Determine which type of triangle having the largest area.

The subject worked on the first mathematical problem on the first day until the third day. The subject worked on the second to fourth mathematical problems consecutively on the fourth day until the sixth day. In the problem-solving process, the researchers did not give scaffolding interaction on the first, fifth, and sixth days, but provided scaffolding interaction on the second to the fourth day.

In the problem-solving process, the subject used the thinking aloud method to observe what the subject thought while working on mathematical problems. According to [30], the thinking aloud method allows the subjects to verbalize every thought they make. In this research, the thinking aloud method used was the subject worked on the problems while explaining loudly why he took and considered his chosen way or how he solved the problems.

Data were collected by recording or documenting the process carried out by the subject during the problem solving and conducting interviews between the researchers and the subject. The results from data collection were analyzed and the analysis results were presented in the form of narrative text.

III. RESULT

The results of the six consecutive day research are presented in the following tables.

Table 1: Overview of Research Results

Day	The Subject's Activities

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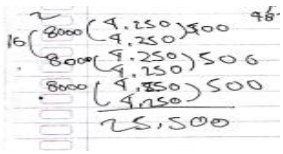
Day	The Subject's Activities
The First Day: • The researcher gave a mathematical problem for the subject at the first meeting. The problem given by the researchers is: • "You want to buy refreshments for your party in various packages; 500 ml which cost Rp. 2,500.00; 1 liter which cost Rp. 4,250.00; 1.5 liters which cost Rp. 6,000.00. You know that 1 liter = 1000 ml. In your party, you need 6 liters of refreshments. Which package is the cheapest for your party?" (The problem was adopted from the mathematical problem from Mokos, 2013). • No scaffolding interaction	• The subject did not understand what was being asked in the problem. It can be seen from the subject read while scratching his head. • The subject only read the problem once • The subject inferred that the problem asked about which the cheapest packages among the three packages were and how much he should pay for 6 liters. • In the worksheet, he wrote 1 liter cost 4250 in his worksheet. But in calculating, he wrote 4250 6 times in a row and then summed it up.  Fig. 1 • The subject was not correct in answering the given mathematical problem. *1 liter costs Rp. 4,250* *6 liters x Rp. 4,250 = Rp. 25,500* • The subject did not recheck his work results.
The Second Day: • The given problem was similar to the first day. • The researchers provided scaffolding by asking the subject to repeat reading the given problem until he understood the purpose and knew what being asked. It was done by the researchers based on the first meeting in which the subject directly worked on it without understanding the problem first.	• The subject understood the problem • The subject still needs a long time to work on the problem • The conversation between the researcher and the subject are the following: Researcher: When you work on a problem, read the problem again and again until you understand the purpose and know what is asked in the problem. Subject: Yes Ma'am. Researcher: Okay, now read the question I gave you yesterday. Subject: Reading aloud the problem in the first meeting (after reading for 2 times), Ma'am, I already understand the purpose of this problem. Researcher: What do you understand the problem? Subject: There are 3 packages of 0.5 L, 1 L, and 1.5 L. Each package has a different price. Well, if the party needs 6 L, which is the cheapest package? That's the purpose of this problem. Am I right, ma'am? Researcher: Okay, right ... good job. Now after knowing the purpose of the problem, what will you do? Subject: Um (while looking at the question sheet). Researcher: Um ... what? Subject: Wait for Ma'am, still thinking... Researcher: What do you think? Subject: (writing 0.5 + 0.5 = 1, 1 + 1 + 1 + 1 + 1 + 1 = 6, 6 x 2) for 0.5 L, I need 12 bottles. For 1 L, I need 6 bottles (writing again 1.5 + 1.5 = 3, 3 + 3 = 6, 2x2 = 4) for 1.5 L, I need 4 bottles. Researcher: And then ... Subject: Then, 12 bottles are multiplied by 2,500, 6 bottles are multiplied by 4,250, and 4 bottles are multiplied by 6,000 (for 12 bottles and 6 bottles, the calculation was arranged down then summed, while for 4 bottles directly 4 x 6000). 12 bottles need 30,000, 6 bottles need 25,500, and 4 bottles need 24,000. So, I'll spend the least money if I buy 4 bottles, 4 bottles of 1.5 L package. *1.5 liters cost Rp. 6,000.00* *2,500.00 x 12 = 30,000* *4,250.00 x 6 = 25,500* *6.000,00 x 4 = 24.000* Researcher: Good... We continue our meeting next week

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Day	The Subject's Activities
The Third Day: • The given problem was similar to the first and the second day. • The researchers provided scaffolding by asking students to pay attention to the time needed for solving the mathematical problem. It was based on the previous meeting, in which the subject takes a long time to work on the problem. • The researchers provided scaffolding by asking the subject to use his prior knowledge in finding the ways to solve the problem. • The researchers provided scaffolding by asking the subject to recheck the answers of his work results.	• The subject can shorten the time in solving the problem • The subject used his prior knowledge • The subject recheck his answers • The conversation between the researcher and the subject are the following: Researcher: Okay, let's continue our yesterday's meeting. Subject: Yes Ma'am. Researcher: Now let's see your results yesterday. You needed a very long time to solve the problem. Now, in solving the problem, you have to estimate the time needed to answer it. You have to think of various ways to solve the problem. Then, choose the fastest way in the process. When choosing the way, use your prior knowledge useful to solve the problem you have. Now, try to think whether there are other ways to solve the problem you did at yesterday's meeting! Subject: Uhmm ... give me a second, Ma'am (while pointing at his answer before). What do you think about this way, Ma'am? (while writing and talking) 12, 6, and 4 bottles I got from 6 liters are divided by package size. To calculate it easily, I convert liters into milliliters. In this way, Ma'am, if I use this way, I can easily and quickly calculate the problem than yesterday. *Explanation:* *If using a 500 ml package, so 6000/5000 x 2,500 = 30,000* *If using a 1 liter package, so 6000/3000 x 4,200 = 25,500* *If you use a 1.5 liters package, so 6000/1500 x 6,000 = 24,000* *So, the cheapest is 24,000 or 1.5 liters package* Researcher: Is there another way? Subject: I don't think there is. Researcher: Now, recheck your answer, did you choose the correct way in doing this problem ... Subject: (Looking back at the answer) It's correct, Ma'am. Researcher: Okay, our meeting today is over. Reflect and apply the strategies I gave when you work on the problem again. See you tomorrow. Subject: Yes Ma'am, thanks Ma'am
The Fourth Day: • The given problem is as follows: • "Someone bought a 90 m2 house for Rp. 150,000.00/ meter. He paid half of the price in advance and the rest in 25 monthly installments. How much the installment should he pay each month?" • The researchers provided scaffolding by reminding the subject to consider the completion time and thinking about the strategies used which enable the appropriate and fast solution. • The researchers provided scaffolding when the subject experienced difficulties in the problem-solving process. • The researchers provided scaffolding by asking the subject to the answers of his work results	. • The subject understood the problem without scaffolding from the researcher • The subject experienced difficulties when calculating half of the house price. When calculating, the subject wrote all the zeros in the house price, causing counting errors occurred. After being given scaffolding by the researcher, the subject solved the problem correctly. *House price = 90 x 150,000 = 13, 500,000* *Down Payment = 1/2 x 13,500,000 = 6,750,000* *The rest to be paid = down payment = 6,750,000* *Installments to be paid = 6,750,000: 25 = 270,000/month* *So, the installments he should pay each month is 270,000* • The subject rechecked the answers without scaffolding from the researcher

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Day	The Subject's Activities
The Fifth Day: Which are the possibilities to form a triangle if there are long sticks provided in the following size? Investigate! a. 11 cm, 12 cm, and 15 cm; b. 2 cm, 3 cm, and 6 cm; c. 6 cm, 10 cm, and 13 cm; d. d. 5 cm, 10 cm, and 15 cm	• Without any scaffolding from the researchers, the subject was aware of his mistakes in the problem-solving process. he then immediately improved according to the prior knowledge. These activities could be seen from the students' thinking aloud as follows: Researcher: I have a mathematical problem, try to solve it! Subject: Yes, Ma'am. (Read the question sheet given by the researcher). From this problem, it is known that there are 4 groups of long sticks. Each group has 3 different lengths. This question asks which of the four groups can form a triangle. Subject: The four groups are all triangles ... Subject: The four groups are triangles because they have 3 sticks, short and long sticks. Triangle has 3 sides with short and long ones. Subject: Um ... give me a second, Ma'am... (while drawing 2 right triangles of triple Pythagoras, 3, 4, 5 and 6, 8, 10). 3 + 4 is bigger than 5, 6 + 8 is also bigger than 10... So, the above question is also like that ... (immediately write on the answer sheet) 1.A problem a (can) - occurs if a | b | c a) a = 11 a. the shortest side (height) b = 12 b. the middle side (base) c = 25 c. The longest side 11 + 12 = 23 > 15 So 23 > 15 can form a triangle b). a + b > c a = 2, b = 3, c = 6 2 + 3 = 6 < 6 cannot form a triangle c). a = 6, b = 10, c = 13 6 + 10 = 16 > 13 So 16 > 13 can form a triangle d). a = 5, b = 10, c = 15 a + b > c 5 + 10 > 15 So 15 = 15 cannot form a triangle
The Sixth Day The given problem is: Given four triangles (arbitrary triangle, right triangle, equilateral triangle, and isosceles triangle) having the same circumference of 24 cm. Determine which type of triangle having the largest area	The results of the subject's thinking aloud could be seen in the following problem-solving process: 1. When the subject determined the length of the sides of an arbitrary triangle and an isosceles triangle, the subject stated: "if I choose a decimal number for the lengths of the sides, I will have difficulty in calculating the area, so I have to choose a round number for the lengths of the sides". Finally, he chose the length of the sides of 6, 7, 11 for the arbitrary triangle and 7, 7, 10 for the isosceles triangle. 2. After determining the lengths of the four triangles, the students' metacognition reemerged when calculating the area of the four triangles. Before calculating the area, he wrote 2 formula of the triangle area, i.e.: a. L = ½ x a x t b. $L = \sqrt{s(s-a)(s-b)(s-c)}$ "If I choose the first formula, I can easily calculate the area of a right triangle, but it will be difficult and take a long time to calculate the area of the other 3 triangles because I have to find the height first. I think I'll use the second formula, the circumference is already known, so to calculate the area, I just need to put the circumference and the lengths of the sides of each triangle. • The subject also did the researcher's suggestion in the previous days. Such as, to repeat reading the given problem until he understood the problem, to consider the time in determining the problem-solving strategy, to relate to his prior knowledge, and to recheck his work results.

IV. DISCUSSION

From the research results, it can be seen that without any scaffolding interaction on the first day, the subject could not solve the given problem. The subject was still lack of the mathematical problem-solving ability. From the answer, it can be seen that the subject could not solve the given problem. On the second to the fourth day, the researchers provided scaffolding interaction for the subject. The provided scaffolding was in accordance with the found problems. It is in line with [26], [16] opinion that scaffolding requires suitability between problems in the task with the provided support so that individuals can process information in their working memory effectively.

On the second day, the researchers gave advice for the subject to repeat reading the given problem until he understood the purpose and knew what being asked. It was done by the researchers because the subject did not understand the given problem on the first day. When viewed in the scaffolding interaction proposed by [24], scaffolding conducted by the researchers applied the reviewing process. On the third day, the researchers asked the student to shorten

the work time and relate prior knowledge in solving the problems. Based on the scaffolding proposed by [24], the researchers applied the restructuring process. In addition, the researchers also asked the subject to recheck the answers of his work results. It was done by the researchers because the subject did not recheck his answer. According to [24], the researchers applied the explaining process. On the fourth day, the subject worked on the problem inaccurately. To overcome this problem, the researchers provided scaffolding in the form of a stimulus to recall the previously-planned methods. According to [24], the researchers applied the restructuring process.

On the fifth and the sixth day, the researchers gave no scaffolding interaction. But the subject's results were different from the first day which had no scaffolding interaction as well. On the fifth and the sixth day, the subject was not only able to solve mathematical problems, but also showed metacognitive activities of awareness, evaluation, and regulation. Indicators of the subject metacognitive activities emergence were based on the metacognitive activity type by [4].

Table 2: Metacognitive Activities in Problem-Solving

Metacognitive Activities	Indicators
Metacognitive Awareness (MA)	The students' expression in relation to their metacognition which indicates awareness to think about: 1. what is known (knowledge related to the task, knowledge relevant to the problem, a personal strategy can be used in problem-solving) 2. their position in the problem-solving process 3. what is needed to do has done and can be done in problem-solving
Metacognitive Evaluation (ME)	Evaluations related to the metacognition which indicates the awareness to think about: 1. effectiveness and limitations of the thinking process 2. the strategy effectiveness 3. assessment of results 4. assessment of problem difficulties
Metacognitive Regulation (MR)	The students' expression related to the metacognitive process which indicates awareness to think about: 1. planning the strategy 2. arranging work steps and objectives 3. choosing the right problem-solving strategy

V. CONCLUSION

Based on the research results, it was found that the scaffolding interactions of explaining, reviewing, and restructuring gradually during 3 meetings were able to develop the three metacognitive activities in the subject. The emergence of metacognitive activities i.e. awareness, evaluation, and regulation in the subject made the subject was able to solve the given mathematical problems.

For future research, it is necessary to consider the research classically, not in one subject only. Therefore, it is necessary to develop a learning model which can construct student metacognition to make students able to solve problems and improve their learning outcomes.

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