

Metacognitive Strategy on Completion of Mathematics Word Problems and Mathematics Achievement among 3rd-Grade Elementary Students

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Abstract

One of the fundamental sciences to be learned is mathematics. In Indonesia, students learn mathematics even from preschool up to higher education. Nevertheless, based on the international studies, the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) in 2015, mathematics achievement of Indonesian students are still ranked at the bottom. Mathematics achievement is closely related to the cognitive domain, which not only requires cognition but also involves metacognition. This research aimed to further examine the relationship between the use of metacognitive strategy on completion of mathematics word problems and mathematics achievement among 3rd-grade elementary students. Participants in this research amounted to 94 students from two elementary schools (one public school and one private school). The results of this research indicated that there was a significant positive relationship between the use of metacognitive strategy and mathematics achievement among 3rd-grade elementary students ($r = 0.35$, $p < 0.01$, 1-tailed). Therefore, students who used metacognitive strategy in mathematics learning showed good mathematics achievement as well.

Keywords: 3rd-grade elementary students; mathematics achievement; metacognitive strategy

1. Introduction

Humans have been exposed to various sciences from an early age, and one of the fundamental sciences to be learned is mathematics. Furthermore, the application of math goes beyond school subjects into everyday life, for instance in shopping and driving. However, in general, individuals' math performance in school is an indicator of general math ability (Nizoloman, 2013).

In Indonesia, mathematics or math is introduced since preschool, starting from the simple introduction of and sorting on numbers. It becomes a compulsory subject from elementary school to higher education. Math is also an essential component in some other subjects in school, such as physics and economics. However, compared to the performance of students from other countries, Indonesian students' math performance was not satisfactory. One of the evidence is that Indonesia currently ranked 64th out of 72 countries in the Programme for International Student Assessment (PISA), and ranked 44th out of 49 countries in the Trends in International Mathematics and Science

Study (TIMSS) (Mullis, Martin, Foy, & Hooper, 2016; OECD, 2016b). Among explanations of the reasons for unsatisfactory performance of Indonesian students is the emphasis on the memorization of formulas in the math curriculum at Indonesian schools (Nurfuadah, 2013).

Satisfactory math achievement demands the utilization of problem-solving skills in the cognitive domain, due to the close association between the two (Lucangeli & Cornoldi, 1997). Good math performance can be achieved when students aware of and control what they should do and how to do it when dealing with a math problem. Thus, metacognition plays significant roles in managing and monitoring of what had been done.

Flavell (1979) defined metacognition as "*thinking about thinking*" (Flavell, 1979), which means knowing consciously about the process of one's self-thinking. Metacognition differs from cognition. Cognition is involved in performing a simple task, such as just reading or recognition. In contrast, the more complicated work requires metacognition, including decision making and monitoring (Garofalo

& Lester, 1985). Furthermore, metacognition also facilitates the function and process of thinking process in a cognitive domain that related to one's problem-solving (Mokos & Kafoussi, 2013).

The metacognitive strategy is even more critical when it comes to math learning process, as students need to decide on the adequate strategy to complete the problem set (Silver in Schneider & Artelt, 2010). One of the challenges that students have to face in learning math is solving a word problem. This kind of problem requires students to construct a problem model by identifying the missing information, specifying the numeric symbols that represent existing and missing data, and perform the correct calculation (Fuchs, Seethaler, Powell, Fuchs, Hamlett, & Fletcher, 2008). However, despite the importance of metacognition in math learning, unfortunately, research on metacognition and mathematics achievement is still rare, especially in the Indonesian context. This research would focus on Indonesian children aged 8-10 years old.

Metacognitive Strategy

Metacognition was defined as knowledge of the self-cognition process (Flavell, 1979). According to Flavell (in Mokos & Kafoussi, 2013), metacognition was active monitoring and regulation of information processing processes to achieve goals. Related to the use of metacognitive strategy, Flavell (in Du Toit & Kotze, 2009), stated that metacognitive approach was the conscious monitoring existing strategies in one's cognitive to achieve specific goals. For example, when students asked themselves about the question at hand and then they would monitor how well they had answered the question. According to Flavell (in Walt & Maree, 2007), a metacognitive strategy involved monitoring, planning, controlling, and evaluating results and reflecting on the overall task.

Metacognition consisted of two aspects: metacognitive knowledge and metacognitive experiences (Flavell, 1979). Metacognitive knowledge was the collection of information related to human beings as well as to various tasks, goals, actions, and experiences. It consists of information and belief about person, task, and strategies, that act and interacts in influencing the outcomes of the thinking process. While metacognitive knowledge pertained to the body of information, metacognitive experiences were the cognitive or affective involvement that accompanied and related to each thinking process. Efklides (2008) added one more aspect to metacognition, which was a metacognitive skill. Metacognitive skill was the use of strategies to

control cognition intentionally (Efklides, 2008). According to Veenman and Elshout (in Efklides, 2008), metacognitive skill consists of several strategies, which were orientation, planning, monitoring of the cognitive process, implementation of planned actions, and evaluation of the results. Desoete (2009), also mentioned some forms of metacognitive skill such as prediction, planning, monitoring, and evaluation. These three aspects of metacognition interacted with one another, in which metacognitive experiences provided information that led to the metacognitive skill, either directly or indirectly through metacognitive knowledge (Efklides, Samara, & Petropoulou, 1999, in Efklides, 2008).

There were several factors found to influence metacognition, both from internal factors and external factors. Some internal factors that affect metacognition included the level of intelligence (Montague & Applegate, 1993; Nader-Grosbois, 2014), self-perception and self-regulation (Nader-Grosbois, 2014). On the other hand, external factors affecting metacognition were social environments such as the effects of school teaching and parental instruction (Carr, Kurtz, Schneider, Turner, & Borkowski, 1989).

The Development of Metacognition

For most children, the development of metacognition took place when children were in preschool and elementary school (Garofalo & Lester, 1985). Children's awareness of metacognition began to emerge at the age of 4-6 years or in the early years of primary school (Demetriou & Efklides, in Ozsoy, 2011). At this stage, children began to realize that his or her thinking process is different from the thinking process of others which is related to the purpose of communication and social interaction (Efklides, 2009). The development of metacognitive knowledge and skill in preschool was at the most fundamental level, then became better and academically oriented when necessary (Veenman et al., in Ozsoy, 2011). By the age of 8, children have developed the capability to monitor the effectiveness of their problem-solving strategy as well as use the insight obtained from the observation for a future problem-solving occasion (Schneider & Artelt, 2010). At the age of 8-9 years, metacognition began to develop thoroughly (Kreutzer, Leonard, & Flavell, in Schneider & Artelt, 2010). Thus, metacognitive development is more mature completely with age.

As mentioned, this the age when children's metacognition began to develop fully. Furthermore, children at this age have acquired specific logical

structures that enabled them to perform various mental operations, including regulating, organizing, and processing information more efficiently (Piaget, in Miller, 2011). In Indonesia, children aged 8-10 years were generally in grade 3 of elementary school. In the context of math curriculum in Indonesia, the age range corresponds to Grade 3, where students start to get introduced to the more complex mathematical concepts (e.g., fraction), operation, and problem sets (e.g., word problem). Drawing from existing literature, therefore, this study hypothesized that the use of metacognitive strategy on completion of mathematics word problems would predict mathematics achievement among third-grade elementary school students.

2. Methods

This study is part of broader research on metacognition among third-grade elementary students in Indonesia. The research team consisted of four undergraduate students and two faculty members.

Sample. The criterion for participants of this research were third-grade elementary students who were 8-10 years old and had an average IQ score and above average, as measured through the Colored Progressive Matrices (CPM) (group III was average, group II was above average, and the group I was superior). We used IQ data as a participants' criterion in this research. Based on data collected, there were 94 third-grade students from Depok, Indonesia, participated in this study. Most of them (47.9%) were 9 (nine) years old. By gender, the ratio of male to female research participants was not much different, with 51.1% were girls. Based on the classification of IQ, most participants' IQ (54.3%) were superior (Group I), 31.9% were above average (Group II), and 13.8% were average (Group III). Meanwhile, based on the origin of the school, 56.4% came from private elementary schools and 43.6% came from public elementary schools.

Research Design. This research used correlational, non-experimental research.

Instruments and Measurements.

Intelligence. There were three instruments used in this research. The first instrument was Colored Progressive Matrices (CPM), to see the level of intelligence or IQ of participants as the initial screening of the characteristics of research participants. CPM is an intelligence test developed by John C. Raven, that is one of the intelligence tests in the Progressive Matrices intelligence test series

(Raven & Raven, 2003). CPM is used to measure intelligence levels for children and adults less mentally aged (Raven & Raven, 2003). Items of CPM are shaped patterns of color drawings that consisting of three parts namely A, B, and Ab. Each section includes 12 items, so the total items in a set of CPM are 36. Scoring technique for CPM was 0 (zero) score for a wrong answer and 1 (one) for a correct answer, so the possible range of score is 0 to 36. Then, we adjusted the scores obtained to the standard score of intelligence, which is the age-based norm and became the basis for intelligence leveling (grouping). Two other instruments used were two mathematics word problems (on thinking aloud measurement technique that was used to measure the use of metacognitive strategy), and the Mathematics Achievement Test to measure students' mathematics achievement.

Metacognitive Strategy. In the think-aloud technique, participants were asked to verbalize their thinking process by talking while solving the given word problems. The data obtained on think-aloud method was coded using coding scheme protocol that applied in a study conducted by Montague and Applegate (1993). It was used to find out which metacognitive strategy students applied while completing word problems. The strategies involved Hypothesizing (H), Estimating (E), Process Checking (CH1), Product Checking (CH2), Attention Control (AC), Self-Correction (SC), Evaluating (EV), Confirming (CO), and Self-Evaluation (SE). Verbatim data obtained from think-aloud technique were then coded based on the coding scheme protocols. Scoring was done by counting the number of categories of emerging strategies, which were given a score 1 for each emerging strategy and then calculating the total number of each strategy category, so the possible lowest score is 0, and there is no limit to the highest score. A higher score means that students more use metacognitive strategy.

Math Performance. The Mathematics Achievement Test used to measure mathematics achievement was an instrument developed by the researcher under supervision from three elementary school teachers and has been adapted to the curriculum in grade 3 elementary school in Indonesia. This Mathematics Achievement Test consisted of 15 questions, with a composition of 10 computation problems and 5-word problems. This test reliability coefficient showed that Cronbach's Alpha = 0.81. The Mathematics Achievement Test developed by the researcher had a reliability coefficient of more than 0.8, which makes it a good measuring instrument based on Anastasi and Urbina (1997). The validity

used corrected item-total correlation showed 14 items were above 0.2 and only 1 item needed to be repaired ($r < 0.2$). Scoring technique for Mathematics Achievement Test was 0 (zero) score for a wrong answer and 1 (one) for a correct answer, so the possible range of score is 0 to 15.

Procedure. Data collection was conducted on May 8 – 12, 2017 at two elementary schools in Depok, West Java, Indonesia. First, the initial screening used the Color Progressive Matrices (CPM) that conducted by two psychologists. The initial screening was performed to determine the level of participant intelligence or IQ, and data was collected from participants with average and/or above average IQ (Group III, Group II, and Group I), which was consistent with the characteristics of the research participants. We conducted the think-aloud technique using the instrument of mathematics word problems for as many as two questions. Implementation of think-aloud measurement technique was done individually. Before data collection, we taught participants first about how to do think-aloud when solving word problems. We also explained in advance the instructions for completing the Mathematics Achievement Test, before giving the test to the participants collectively.

3. Results

To test our hypothesis, we used Pearson correlation analysis to investigate the relationship between the use of metacognitive strategy in the completion of word-problems and mathematics achievement among third-grade elementary school students. The results showed that there was a significant positive relationship between metacognitive strategy and mathematics achievement ($r = 0.35$, $n = 94$, $p < 0.01$, 1-tailed). It suggests that the higher metacognitive strategy predicted higher math performance, particularly performance in solving math word problem. The obtained value of $r^2 = 0.12$ means that 12% of the variability in mathematics achievement could be explained by metacognitive strategy, which indicates a moderate association between metacognitive strategy and mathematics achievement.

4. Discussion & Conclusion

Discussion. The purpose of this research is to examine the relationship between metacognitive strategy on completion of mathematics word problems and mathematics achievement among third-grade elementary school students. The result of this research supported the notion of the significant relationship between the use of metacognitive

strategy on completion of mathematics word problems and mathematics achievement among 3rd-grade elementary students. This result supports the hypothesis we proposed. It is also consistent with Borkowski and Thorpe (in Ozsoy, 2011), which stated that metacognition affects success in mathematical learning, reflected in successful mathematics achievement. The significant relationship in this research could be explained by Carr, Alexander, and Folds-Bennett (1994), who stated that metacognition involved when students faced challenging tasks, including mathematics. Students often regard mathematics as a scourge and difficult thing. Anderson (2010) argued that the use of metacognitive strategy when faced with challenging task, could trigger students' thinking process and improve their performance.

The relationship shown in the results of this research was a significant positive relationship, which meant that the improvement of metacognitive strategy score was followed by an increase in mathematics achievement score so that students with low metacognition then have low mathematics achievement as well. These results are in line with a study conducted by Desoete, Roeyers, and Buysse (2001), which found that low achievers show a deficiency in the use of metacognitive strategy compared with middle and high achievers. These results are also consistent with a study conducted by Schneider and Artelt (2010), which showed that students who had high achievement in math tests know more and tend to be more involved in using their metacognitive strategy. The findings could be explained by Pintrich's statement (in Young, 2010), which stated that students with high metacognition were better able to adjust their thinking processes when solving problems, were better able to apply strategies to new situations, and had better performance than students who had low metacognition. Students with good mathematics achievement also demonstrated the skills of selecting relevant information and the ability to use various strategies for success in mathematics (Schneider & Artelt, 2010). This finding is consistent with the study results of Verschaffel et al. and Cardel-Elawar (in Kramarski, Mevarech, & Arami, 2002), who found that the cause of low-achieving students was the difficulty in sorting information, the tendency to use only commonly used ways, and unsure of computation operation and its application.

The results and findings of this research are expected to be applied in the learning of mathematics in grade 3 of elementary school. The outcome of this research, it can be seen that students who use metacognitive strategy get high math achievement as

well. Therefore the use of metacognitive strategy needs to be applied in mathematical learning so that students could improve their performance. In addition to that, it is necessary to teach students the "think-aloud" strategy, especially for they studying mathematics. It is so they could understand their thinking process and monitor what it did, which could then find out if there was an error and minimize further mistakes.

We realize the limitations of this study. The first one is the representativeness of our sample, since the schools that participated only schools in Depok region. We also did not consider the school's type or accreditation, that may influence the students' characteristics. Besides that, even though the preparation of the test has been quite good, we did not involve teachers directly in making the problems. We involved teachers only in determining the suitability of the items with the curriculum on grade 3 elementary school.

Conclusions. Based on the results and findings of this research, it can be concluded that there is a relationship between metacognitive strategy on completion of mathematics word problems and mathematics achievement among third-grade elementary students. An increase in the metacognitive strategy score then the math achievement score will increase as well.

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