Metacognition Difficulty of Students with Visual-Spatial Intelligence during Solving Open-Ended Problem

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Abstract. This study aims to find out students metacognition difficulty during solving open-ended problem in mathematics. It focuses on analysing the metacognition difficulty of students with visual-spatial intelligence in solving open-ended problem. A qualitative research with case study strategy is used in this study. Data in the form of visual-spatial intelligence test result and recorded interview during solving open-ended problems were analysed qualitatively. The results show that: (1) students with high visual-spatial intelligence have no difficulty on each metacognition aspects, (2) students with medium visual-spatial intelligence have difficulty on knowledge aspect on strategy and cognitive tasks, (3) students with low visual-spatial intelligence have difficulty on three metacognition aspects, namely knowledge on strategy, cognitive tasks and self-knowledge. Even though, several researches about metacognition process and metacognition literature recommended the steps to know the characteristics. It is still important to discuss that the difficulties of metacognitive is happened because of several factors, one of which on the characteristics of student’ visual-spatial intelligence. Therefore, it is really important for mathematics educators to consider and pay more attention toward students’ visual-spatial intelligence and metacognition difficulty in designing better mathematics learning.

1. Introduction

Nowadays problem solving has become mathematics learning process orientation in many countries include Indonesia. Problem solving has been considered as an important and integral component of mathematics learning process. Problem solving becomes one of process standard [1] and main competence [2] should be improved in mathematics learning process. Mathematics learning process oriented on problem solving could improve students thinking ability. The improvement of students thinking ability is very essential and required for students to face the problem either in learning process context or real-problem context.

Based on the report of Trends in International Mathematics and Science Study (TIMSS) 2011 [3], Indonesia ranked 38 of 42 countries with the overall score mean is 386. The result of Programme for International Student Assessment (PISA) 2015 [4] showed that Indonesia ranked 63 out of 70 countries regarding with mathematics problem solving ability. In addition, more than 60% Indonesian students were only able to complete mathematics problem under level 2. It indicates the poor of mathematics problem solving ability of Indonesian students. Furthermore it is important for mathematics teachers to consider and evaluate mathematics learning process due to the poor result of Indonesian students regarding with mathematics problem solving ability.
Actually the poor result regarding mathematics problem solving of Indonesian students is caused and affected by many factors. Heong said that weakness in understanding concepts, logic-thinking and lacking of strategic knowledge caused errors in problem-solving [5]. In addition, Johan stated that many students could not bring meaning to the problems and did not know how to plan and perform the problem-solving strategies [5]. Mathematics learning process in Indonesia was still mechanistic, that teachers explained formulas, algorithms, examples, and then students did the exercise according to the example provided by the teacher [6]. Those opinions above indicates that mathematics learning process still tend to be seen as a process of cognition that promotes students’ rote related to concepts, formulas, and strategies. Furthermore, it leads students to have no deep understanding about the concept, formula, strategy, and the overall material. The learning process also can cause the lack of meaningfulness of knowledge learned by students.

Problem solving activity in mathematics learning process does not only relate to the knowledge and procedure involved students’ cognition operation. It also requires the thinking awareness of students for controlling and regulating their thinking process. Risnanosanti stated that problem solving was a complex process involved metacognition [7]. It is also relevant to the Stenberg statement said that students needed metacognition skill, in addition to cognitive component, to regulate and monitor the problem-solving process [8]. Thus, it can be concluded that metacognition process is required for students in solving mathematics problem in order to improve problem solving ability.

According to Flavell metacognition can be defined as an individual’s knowledge about his/her own cognitive processes [9]. On the other hand, Brown defined metacognition as students’ awareness and organization of thinking processes that they use in planned learning and problem solving situations [10]. In addition, Swanson defined metacognition for learning process context as individuals’ awareness of their ability to monitor, regulate and control their own activities concerning learning [10]. Ozsoy stated that metacognition involved awareness regarding the learning process, planning, choosing a strategy, monitoring learning process, to be able to correct one’s own mistakes, to be able to check whether the strategies used is useful or not, to able to change the learning method or strategy when necessary [11]. Based on several opinions above it can be defined that metacognition is individual’s awareness and understanding regarding his/her cognition process and the ability to control and regulate the cognition process.

Anggo [12] stated that the metacognition process is the self-awareness and self-regulation of thinking during solving problems activity. Schoenfeld specifically stated that metacognitive processes included assessing one’s own knowledge, formulating a plan of attack, selecting strategies, and monitoring and evaluating progress [13]. Thus, metacognition process involves awareness and reflection regarding individual’s knowledge of cognition and regulation of cognition process. Metacognition process can be defined as a process involved awareness of thinking in using and optimizing individual’s knowledge of cognition through regulation of the cognition process.

Metacognition in this research is a person’s awareness towards thinking process and result. Metacognition consists of 3 aspects, namely strategy knowledge, knowledge about cognitive task, and self-knowledge. The identification of metacognition aspects are namely knowledge on strategy, knowledge on cognitive tasks, and self-knowledge [14].

Students’ success on solving mathematics problem is also influenced by internal factor like visual-spatial intelligence. Visual-spatial intelligence is a skill to capture visual space precisely [15]. According to Hass, the characteristic of visual-spatial intelligence consists of imaging, conceptualization, problem solving, and pattern seeking. Visual-spatial intelligence needs perspective understanding and geometric form. It connects spatial concept and numbers, and skill in transforming mental of visual imagination. A research conducted by Ozlem, states that successful students in mathematic have better intelligence than other students [16]. Boakes states that visual-spatial is an important part in geometry thought [17].

One of the strategies that are considered capable of delivering a positive impact towards problem-solving ability is with problems Open-ended. Open-ended problems is a problem that is formulated to have a multiple correct answers referred to problems of incomplete or also called Open-
ended problems or is open to question [18]. Open-ended problems refer to questions or issues that have more than one correct answer and have more of a strategy or a way to get an answer. Hancock stated that the question of Open-ended is a matter that has more than one settlement and the correct solution [19].

Based on the explanation above, both metacognition and visual-spatial intelligence are essential component and factor in mathematics problem solving activity. Even though, several research about metacognition process and metacognition literature recommended the steps to know the characteristics, it is still important to discuss that the difficulties of metacognitive is happened because of several factor. Unfortunately, there are still few researches regarding the exploration of metacognition difficulty in solving mathematics problem of students with visual-spatial intelligence. Therefore this present research aims to analyse and describe metacognition difficulty of students with visual-spatial intelligence in solving open-ended problems in mathematics. It focuses on analysing the metacognition difficulty of students with visual-spatial intelligence.

2. Method
This research is descriptive analysis research using qualitative method with case study strategy. Qualitative research was a research aimed to understand phenomena regarding subject’s experience holistically through the description in the form of word and language [20]. Thus qualitative research with case study strategy is a research aimed to investigate and understand in deep and holistically contextual phenomena experienced by subject. In this research the contextual phenomena is metacognition difficulty of students with visual-spatial intelligence in solving open-ended problem.

This research was held at SMA in Surakarta, Indonesia since February until April 2017. Subject in this research involve 12 students of 11th grade chosen with purposive sampling. Subject in this research have a visual-spatial intelligence and considered to be able to communicate their own idea or thinking process during solving the given problem.

Data in this research is in the form of video record of mathematics-task based interview. The video record was also transcribed by researcher in order to help for analysing process. The result of interview was used to obtain information of subjects’ metacognition process during solving mathematics problem. Before subjects were interviewed, researcher asked the students to complete visual-spatial intelligence test to obtain information about students’ visual-spatial intelligence level. The instruments in this research namely visual-spatial intelligence test, Open-ended problem solving task, and guidance interview sheet were validated by 3 expert validators for each instrument. In addition, before using visual-spatial intelligence test, researcher tested for trial the instrument to measure items internal consistency and the reliability. The results of visual-spatial intelligence test trials were imposed on 90 students showed the internal consistency index of items $r_{xx} \geq 0.3$ with reliability coefficient $r_{11} = 0.92$.

Data collecting to obtain the information about subjects’ metacognition difficulty was done two times for each subject. In first step, subject was asked to solve open-ended problem solving task 1, involve a mathematics problem about geometric, while researcher also conducted the interview during problem solving activity. Second step for collecting the data was done with the same procedure to the first step using open-ended problem solving task 2. After that, researcher analysed the findings qualitatively to describe subjects’ metacognition difficulty in solving open-ended problem in mathematics. Data were analysed with Miles and Huberman steps of analysing involve data reduction, data display, and verification [21].

3. Result and Discussion
Table 1 describe the result of visual-spatial intelligence level for the research subjects that involve 12 students of 11th grade in SMA in Surakarta, Indonesia. It describes subjects’ visual-spatial intelligence score and its level. Based on the result in Table 2 seems that subjects were identified in the high, moderate, and low level of visual-spatial intelligence. In addition, the subjects also were considered to be able to communicate their own idea and thinking process during solving mathematics problem.
Table 1. Description of Subjects’ visual-spatial intelligence

| Subject | Visual-spatial Score | Visual-spatial Level |
|---------|----------------------|----------------------|
| SPT1    | 82                   | High                 |
| SPT2    | 80                   | High                 |
| SPT3    | 80                   | High                 |
| SPT4    | 78                   | High                 |
| SPR1    | 64                   | Medium               |
| SPR2    | 62                   | Medium               |
| SPR3    | 60                   | Medium               |
| SPR4    | 60                   | Medium               |
| SPL1    | 52                   | Low                  |
| SPL2    | 50                   | Low                  |
| SPL3    | 48                   | Low                  |
| SPL4    | 44                   | Low                  |

The result of interview taken by researcher involve mathematics-task based interview for step 1 and step 2. Based on the interview result for all the subjects either in step 1 or step 2, it can be describe the summary of metacognition difficulty for each aspect and identified elements as follow.

3.1. Student’ metacognition of high visual-spatial intelligence

Students with high visual-spatial intelligence have no difficulty metacognition in solving open-ended problems in geometric material. The result of the research shows the metacognition process of students of high visual-spatial intelligence, namely: 1) in the knowledge aspect of the student strategy to determine the appropriate reading strategy and realize why the students use the reading strategy so that they can understand the problem well, write and identify the information given in the question which includes information that is known and asked by summarizing information that is considered important in solving problems, repeating important terms when solving problems and mentioning the reasons for repeating terms, linking previous concepts to concepts used in problem solving and mentioning the reasons of the use of the concept, interpreting the problem into a more operational form and mentioning the reasons, knowing the purpose of the questions, asking on yourself when solving the problem and mentioning the reasons for doing so, and re-reading the part that is not understood and being sure that there is no error when solving the problem. 2) In knowledge aspect about cognitive tasks, students know what algorithm is used and steps to solve question and mention the reasons and realize when to use a strategy. 3) In self-knowledge aspect, students realize that there is no difficulty in determining the steps to solve the problem and being confident in the steps or strategies made and realizing that the steps are correct. Students who have high visual-spatial intelligence, show that they can present information and images relevant to the problem (imaging), students can determine the pattern of the material presented (pattern seeking), students can solve problems correctly (problem solving), and students can determine the concept of the problem and relate it to the previous knowledge (conceptualization). Based on these characters, subjects with high visual-spatial intelligence master all visual-spatial aspects so they do not have any difficulty on each aspect of metacognition in solving open-ended problems in geometric material.

3.2. Student’ metacognition of medium visual-spatial intelligence
Based on the Table 2, students with medium visual-spatial intelligence have difficulty metacognition in solving open-ended problems in geometric material, namely: 1) In the knowledge aspect of the students’ strategy to know the purpose of the questions, but difficult to use the distance concept between the two fields on geometry. Students cannot link the previous concepts with the concept that is used in solving problem and being able to mention the reasons of the use of the concept., and the students do not re-read the part that is not understood, and be sure to find no mistake when solving this problem whereas the completion step used is not appropriate, and they do not correct the mistake even though the students feel confused about the completion step, 2) In the aspect of knowledge on cognitive tasks, students know what algorithm used. However, it finds mistakes in solving the problem. The difficulty of metacognition process experienced by the students based on visual-spatial intelligence is caused by students who cannot solve the problem solely (problem solving) and students are unable to determine the concept of the problem and relate it to the conceptualization.

| Metacognition aspect | Identified elements | Students’ metacognition on medium visual-spatial intelligence |
|----------------------|---------------------|-------------------------------------------------------------|
| Planning cognitive activity | Students know the purpose of the questions, but they can’t use the distance concept between the two fields on geometry |
| Controlling | Students do not read again the part that is not understood and be sure to find no errors when solving the problem, whereas the completion step used is not appropriate. The subject also does not correct the error. |
| Knowledge on cognitive activity | Procedural knowledge | Students know what algorithm is used but still find error step in solving problems. |

3.3. Student’ metacognition of low visual-spatial intelligence

Based on the Table 3, students with low visual-spatial intelligence have difficulty metacognition in solving open-ended problems in geometric material, namely: 1) In the knowledge aspect of strategy, students are difficult to connect the previous concepts with the concept that is used in solving problem and not being able to mention the reasons of the use of the concept and they can’t mention the reason of the concept use, know the purpose of the questions but the students can’t use distance concept between the two fields on geometry, do not ask themselves when solving the problem and do not mention the reason for doing it, and do not read again to the part that is not understood and students are sure not to find errors when solving this problem whereas the completion step used is not appropriate, and they do not correct errors even though students feel confused about the completion step, 2) In the knowledge on cognitive tasks, students do not know what algorithm used and step in the strategy and students are not aware of when to use a strategy, 3) In aspect of self-knowledge, students are not aware that students find difficulty in determining the steps to solve the problem and they are not aware of the wrong completion steps, but they remain believing if the student completion step is correct and have answered what is asked on the question. The metacognition difficulty faced by students with low visual-spatial intelligence is caused by students who cannot present information or images that are relevant to the problem (imaging), students cannot determine the pattern of the material presented, the student cannot solve the problem with the right solution, and students cannot determine the concept of the problem and associate it with prior knowledge (conceptualization).
Table 3. Students’ Metacognition of Low Visual-Spatial Intelligence

| Metacognition aspect | Identified elements | Students’ metacognition on low visual-spatial intelligence |
|----------------------|----------------------|----------------------------------------------------------|
| **Knowledge on strategy** | **Organizational** | Students cannot interpret the problem into a more operational form and be able to mention the reason of turning the story into a more operational form. |
|                      | Planning cognitive activity | Students know the purpose of the questions, but they cannot use the distance concept between the two fields on geometry |
|                      | Monitoring | Students ask themselves when solving a problem and not mentioning the reason why the subject do it |
|                      | Controlling | Students do not read again the part that is not understood and be sure not to find errors when solving the problem, whereas the completion step used is not appropriate. The subject also does not correct the error |
| **Knowledge on cognitive task** | **Procedural knowledge** | Students do not know what algorithm is used and steps to finish the questions. |
|                      | Conditional knowledge | Students are not aware of when to use a strategy |
| **Self-knowledge** | Awareness | Students do not realize that they find difficulty in determining steps to solve problems. |
|                      | Belief | The student is unaware of the wrong completion steps, but they remain believing if the subject completion step is correct and has answered what the questions are. |

Based on the above description, there are students’ different ability on metacognition. This is supported by previous research conducted by Alfiyah and Siswono which states that between students who solve math problems correctly and students who make mistakes in solving mathematics problems have different metacognition capabilities [22]. Du Toit research that there were no metacognitive behaviours that identified in Polya’s fourth phase [23]. In addition, in the relation to the type of visual-spatial intelligence, supported by research conducted by Boakes states that visual-spatial is an important part in geometry thought [17]. Sudia states that the purpose of learning geometry is to develop the ability to think logically, develop spatial intuition, invest knowledge to support other materials, and be able to read and interpret mathematical arguments [24]. The ability to solve mathematical problems is influenced by students’ visual-spatial intelligence, such as the result of research conducted by Ozlem, mentions that “the students who have high mathematical success have more success in spatial visualization success than others” which means that students who are
successful in mathematics have more visual-spatial ability than any other students [16]. Thus, it can be said that students with high visual-spatial intelligence can used their metacognition process optimally.

4. Conclusion
The result of this research shows that students with high visual-spatial intelligence have no difficulty on each metacognition aspects, students with medium visual-spatial intelligence have difficulty on knowledge aspect on strategy and cognitive tasks, and students with low visual-spatial intelligence have difficulty on three metacognition aspects, namely knowledge on strategy, cognitive tasks and self-knowledge.

It shows that visual-spatial intelligence can cause of students’ metacognition process in solving open-ended problems to be not optimal. Furthermore, this condition leads the students to the lack of mathematics problem solving abilities. Therefore, it is really important for mathematics educators to consider and pay more attention toward students’ visual-spatial intelligence and metacognition difficulty in designing better mathematics learning. Selection of models, methods, strategies, and media of mathematics learning is expected to be able to optimize the level of visual-spatial intelligence as well as optimize the students’ process of metacognition.

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