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Design of problem-solving questions for measuring student's mathematical thinking type representation

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Abstract. This study is design research aimed to describe the design result of problem-solving question that can be used to measure mathematical thinking type representation. The process of this study consists of five stages, namely: preliminary design, focus group discussions (FGD), trials, observation and interview, and retrospective analysis. The subjects of this study are three students. The technique for data analysis was qualitative. The instrument consists of test and directive interview. Based on preliminary design and FGD stages, researchers have designed two problem-solving questions. Based on the results of the trials, observations and interviews, all these questions can lead students' mathematical thinking type representation. This is illustrated by the results of research subjects' answers when working on questions that showing symbolic representation, numeric representation, and visual representation. Symbolic representation is seen from the completion of students who use symbols to solve problem number 1 and 2. Visual representation is seen from students resolve the problems using images to solve problem number 2. Numeric representation is seen from students solving problems using a trial and error strategy and then doing mathematical calculations to make sure the correctness of answers. This is done by students in working on questions number 1.

1. Introduction

Problem-solving is one very important part of mathematics learning [1]. Problem-solving ability is a general goal of teaching mathematics, even as the heart of mathematics; problem solving includes methods, procedures, and strategies are the core and main processes in the mathematics curriculum; and problem solving is the ultimate in learning mathematics [2]. This is also in accordance with the principles that exist in the 2013 curriculum which states that problem solving is an important part of mathematics learning and the ability to solve problems becomes something that must be achieved by students. Problem solving skills are also used in curricula from other countries [3]. Based on the description above, problem solving is an important part of mathematics learning, but students in Indonesia have not met these expectations. The three-year PISA survey conducted by the OECD shows that Indonesia's ranking for mathematics is still relatively low. Based on the results of the OECD survey in 2012, Indonesia's ranking is very concerning, ranking 64th out of 65 participating countries [4]. The scores of Indonesian students in mathematics perched only on the number 375 (scale 0-800), whereas the average score was 494. And the latest PISA results in 2015 which were announced in early December 2016 showed Indonesia's ranking increased from the previous 63rd rank from 69 countries participants [5]. Scores obtained by Indonesian students in the field of mathematics sit at number 386 (scale 0-800) with an average score of 490. Although the blade has increased but Indonesia's ranking is still ranked 10 countries with the lowest value. The same thing happened in the TIMSS survey which showed that

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Indonesia's ranking for mathematics was also still low. The results of a recent survey conducted by the IEA in TIMSS 2015 stated that the ranks of Indonesian students were 36 of the 49 countries that took part in the survey. The score obtained by Indonesian students perched on number 397. The framework of the 2015 PISA mathematical literacy assessment states that one of the process abilities involved in PISA is problem solving ability. The 2015 TIMSS Framework also mentions that problem solving skills are central to implementing domains in the TIMSS cognitive dimension. The low performance of Indonesian students above may be caused by several factors including the learning process that occurs in school or the type of problem is the problem of problem solving or perhaps the inability of students to use mathematical thinking skills or mathematical thinking when solving problems. In the learning process, generally there are two activities that should be done by the teacher in learning mathematics in school, namely the activities of mathematical thinking that think empirically and think mathematically [6]. Empirical thinking is more bound by empirical phenomena which then develop and become the basis of science, which is related to the use of mathematical facts, concepts, and procedures. whereas mathematical thinking develops more freely, not bound by phenomena. Mathematical thinking is more tied to a reasonable thinking/ reasoning structure, although there are no empirical objects or cannot be described empirically.

Mathematical thinking is defined as a thinking ability related to the ability to use reasoning and rational to develop mathematical arguments and procedures, the ability to develop strategies or methods, understanding mathematical content, and the ability to communicate ideas [7]. When faced with a problem, the brain will work systematically so that it will be easier to solve problems. This process that occurs in the brain is known as mathematical thinking. Deep mathematical knowledge, general thinking skills, knowledge of heuristic strategies are part of mathematical thinking [8]. Furthermore, he added that mathematical thinking generally consists of several processes, namely: Specializing, generalising, conjecturing, and convincing. Mathematical thinking is defined as activity developing a mathematical point of view, assessing mathematical processes and abstractions, and always tending to apply them [9]. According to his perspective, Schoenfeld argues that mathematics is an activity carried out in the human mind by using abstraction, symbolic representation, and symbolic manipulation, which he describes as a mathematical tool [9]. Many types of mathematical thinking processes have been explored and identified in mathematics education. It is possible to categorize thinking skills in various ways. Karadag categorizes mathematical thinking into several themes, one of which is representation mathematics [10]. Representation is expressions of mathematical ideas that students display in their efforts to find a solution to the problem at hand [1,11,12]. Thus, representation plays an important role, namely to convert abstract ideas or ideas into concrete concepts, for example with images, symbols, words, graphs, tables and others. In the process of problem solving, students' abilities in concept representation have a very important role [13,14]. A complex and complex problem can be simpler by using mathematical representations.

Based on the description above, it is necessary for designing problem solving questions that can lead students' mathematical thinking type representation. Based on this background, the researchers intend to conduct the study about Design of Problem-solving Questions for Measuring Student's Mathematical Thinking Type Representation.

2. Research methodology

This study is design research aimed to describe the design result of problem-solving questions that can be used to measure mathematical thinking type representation. This study consists of five stages, namely: preliminary design, focus group discussions (FGD), trials, observation and interview, and retrospective analysis [15]. The subjects are three students. The instrument consists of test and directive interview. The technique for data analysis was qualitatively. This study focuses on cognitive activities from the type of representation mathematics students namely: symbolic representation [16], numeric representation [17], and visual representation [18]. Test data analysis is done by correcting the results of students answers when completing test questions that have ben design and then researcher interviews the students to explore more deeply about students' mathematical thinking when solving the problems.

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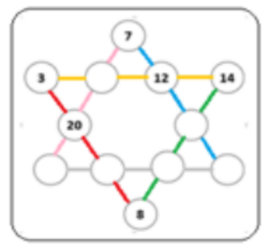
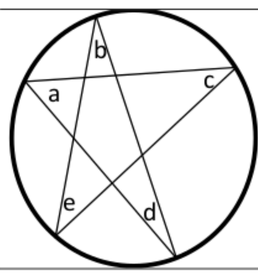
3. Results and discussion

3.1. Preliminary design
The researchers design two problem-solving questions. The process of designing questions as research instruments is done by searching, reading and reviewing some literature from various references on problem-solving and mathematical thinking types of representation to design questions that can measure mathematical thinking students on aspects of mathematical representation. The researcher designs the grid, writing indicators, writing test instruments based on the criteria of problem-solving problems.

3.2. Focus group discussion
At this stage the results of problem-solving designation were consulted by two lecturers and a teacher to see whether the questions in the study were in accordance with the criteria of problem-solving problems which one of the criteria was that it had many settlement strategies [19,20]. The following is the result of designing problem-solving question by the researcher after focus group discussion stages.

Table 1. Problem solving questions designed by researchers.

No.	Questions	
1.	Fill in the empty spheres in a star-shaped arrangement above with different natural numbers so that the sum of numbers in one line for each color has the same number!	
2.		In the following figure, a, b, c, d, and e respectively state the angle at the five-star end points located in a circle. Amount of $a + b + c + d + e = \cdots$

3.3. Trials
At this stage a trial was conducted on the subject. The question was tested on 3 students, namely subject-1, subject-2, subject-3. The length of time given in working on three problem solving items is 60 minutes with the details of each problem being worked out in a maximum of 20 minutes.

3.4. Observation and interview
At the time of the trial, researchers conducted observations about the study to see how their thinking process was when working on the problem using a video recorder or sound recorder. After the three students finished working on the questions, the researcher conducted an interview to the three subjects to get more in-depth information about students' mathematical thinking in when solving the problem.

3.5. Retrospective analysis

3.5.1. Analysis of question number one. The subject-1 resolves the problem with numeric representation, which represents a problem through numbers and involves mathematical calculations.

See figure 1. Even though the answer of subject-1 was not right but after being interviewed it turned out that subject-1 understood the problem. The subject-2 also resolves the problem with cognitive activity as the same as subject-1, that is numeric representation. It seen from subject-2 when solving problems using a trial and error strategy and then doing mathematical calculations to make sure the correctness of the answer.

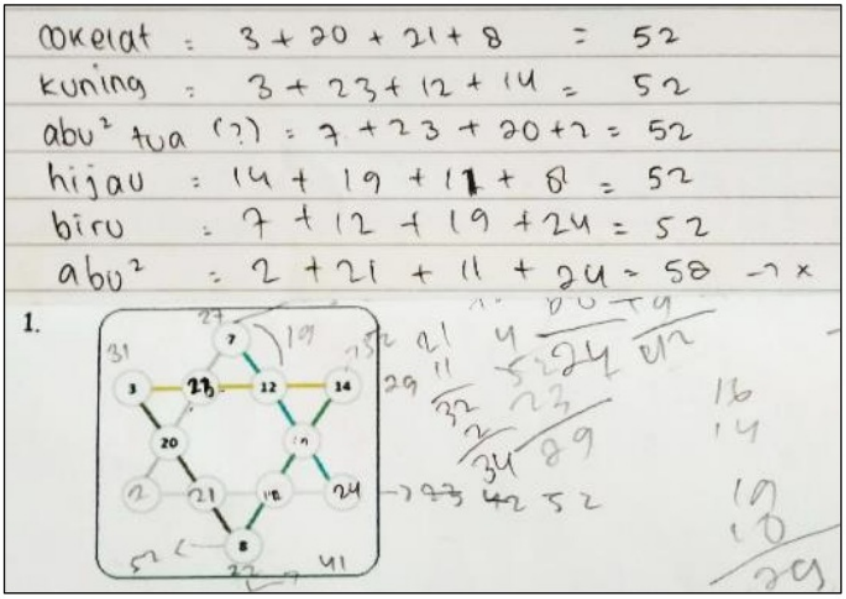


Figure 1. Results of subject-1 completion on question number one.

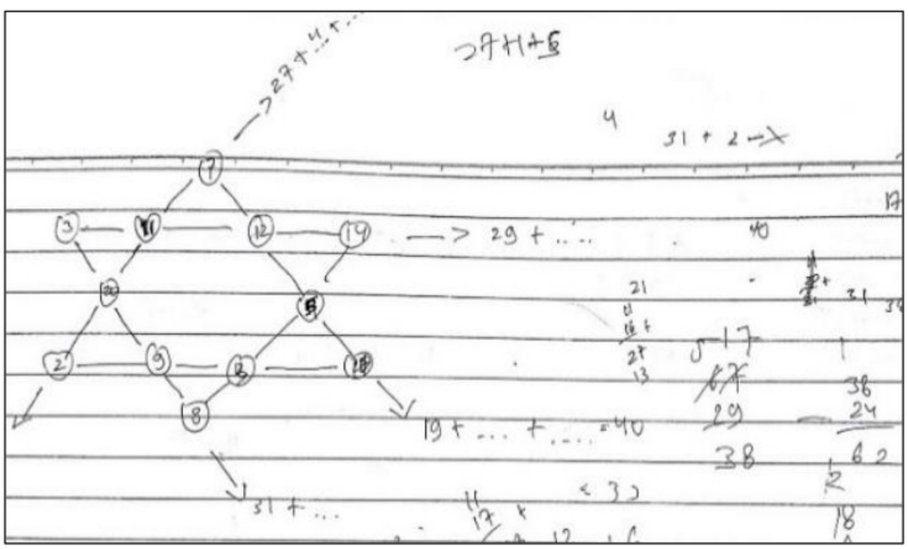


Figure 2. Results of subject-2 completion on question number one.

The subject-3 resolves the problem with symbolize the empty spheres by the variable of "a, b, c, d, e, and f". Then, make the equation from the variable which are knowns. The cognitive activity of students-3 is namely symbolic representation. It seen from the completion of subject-3 who use symbols to solve the problem number one. See figure 3.

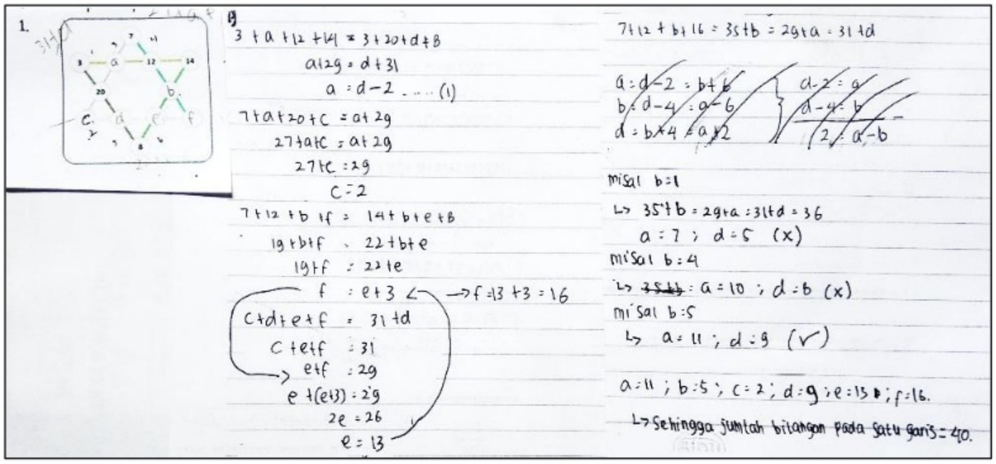


Figure 3. Results of subject-1 completion on question number one.

3.5.2. Analysis of question number two. The subject-1 answers the problem by using the formal form or using the formula to solve the problem number two. See figure 4. But, this cognitive activity not included in categorizes the type of representation by the researcher.

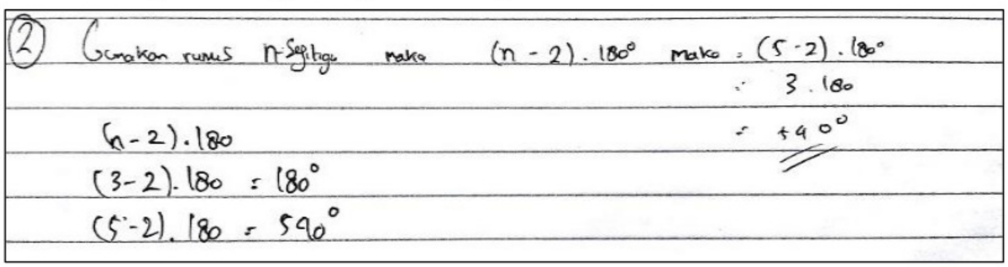


Figure 4. Results of completion of number 2 subject-1.

The subject-2 analyzes the image by looking at the relation of the "c" angel as a half of "f" angel, the "d" angel as a half of "g" angel, and so on. See figure 5. The cognitive activity of subject-2 namely visual representation.

The subject-3 resolve the problem by looking at the relation of the angel "a, b, c, d, e" which form a triangle. See figure 6. The cognitive activity of subject-3 namely symbolic representation. It is seen from the completion of subject-3 who use symbols to solve the problem.

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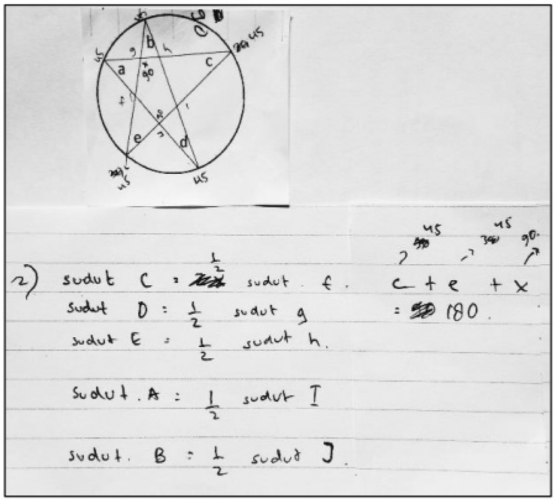

Figure 5. Results of completion of number 2 subject-2.

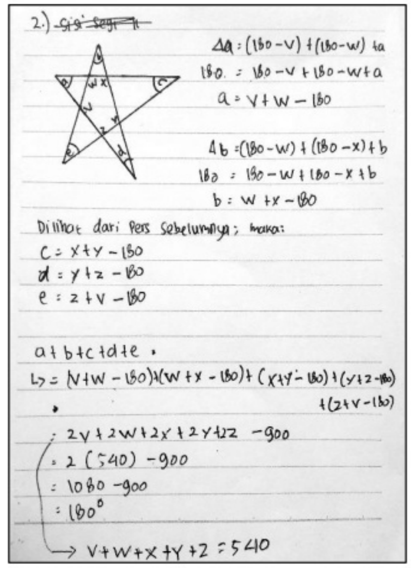

Figure 6. Results of completion of number 2 subject-3.

4. Conclusion

This research has produced two problem solving questions that are able to measure mathematical thinking of students on aspects of mathematical representation. This is illustrated by the results of research subjects' answers when working on questions that showing symbolic representation, numeric representation, and visual representation. Symbolic representation is seen from the completion of students who use symbols to solve problem number 1 and 2. Visual representation is seen from students resolve the problems using images to solve problem number 2. Numeric representation is seen from students solving problems using a trial and error strategy and then doing mathematical calculations to make sure the correctness of answers. This is done by students in working on questions number 1.

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