Level of student understanding in solving geometry problems based on taxonomy of SOLO (Structure of Observed Learning Outcomes)

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Abstract. This research aimed to determine and classify the level of student understanding in solving geometry problems with taxonomy of SOLO (Structure of Observed Learning Outcomes). The material been examined was the geometry of planes and spaces. This research was a type of qualitative research conducted by the method of think loud. The research results were: 55% of students had an understanding that was at a multistructural level with indicators that have been able to use some concepts that was correct but not yet right in terms of linking concepts and 39% of students have been able to use a correct concept (unistructural level). Then about 5% of students have an understanding at the relational level that have been able to use some correct concepts and connect them, whereas 1% of students have a level of prestructural understanding. Based on the research results, it can be concluded that levels of student understanding in solving geometry problems are various from pre-structural level until relational level.

1. Introduction
Students’ understanding about the presented matter must be measured as evaluation to determine the next teaching strategies and to analyze students’ problem solving skills. The better the understanding they have, the better the problem solving skills they obtain. Problem solving skills are important skills and must be developed and owned by students [1]. Problem solving skills are needed skills in daily life [2]. Therefore, in recent years, many researchers have taken up the topic of problem solving [3-5].

The results of preliminary observations had been obtained after students did several quizzes during learning the matters. The results showed that many students still did not have adequate problem solving skills. The quality of the given answers was various according to their understanding levels. So, information about students understanding level in solving problems must be known and classified. With the information, lecturers could plan the teaching strategies to improve students’ problem solving skills. Classifying of students’ understanding level used Taxonomy of SOLO (Structure of Observed Learning Outcomes).

The SOLO (Structure of Observed Learning Outcomes) taxonomy was developed by Biggs and Collis in 1982 [6]. This taxonomy divides the level of quality of the responses or answers of the given problems into five levels; prestructural, unistructural, multistructural, relational, and extended abstract. SOLO’s taxonomy has been widely used by previous researchers [7-10]. The research studies included: using SOLO taxonomy based on a framework to assess students’ informal inferential reasoning,
formulating a theoretical framework of the ability to solve algebraic problems by using SOLO taxonomy, analyzing the spatial ability of mathematics teachers by using SOLO taxonomy, assessing student responses in explicit discussions by using SOLO taxonomy, assessing students' understanding of Teaching Game for Understanding (TGfU) with the two-cycle SOLO taxonomy model, developing a five-step framework in interpreting tables and graphs based on SOLO taxonomy, and constructing tests to access understanding in learning computer science with scratch method based on SOLO taxonomy.

Geometry as one of the compulsory subjects in the mathematics study program has many applications in real world life, for example the problem of a large plot of land, a garden, a rice field, the volume of a tank, or a congruence application to calculate the height of an object without having to climb it directly. Therefore geometry is also studied in schools both elementary and secondary levels. But when solving the problem of geometry of planes and spaces, there was still many students whose answers was not perfect. The answers they gave vary according to their level of understanding.

Research related to the subject of geometry had been carried out by previous researchers. One of the topics of the research was to examine the potential links between mental models built by students, the quality of prior geometry knowledge and their use during problem solving. This study found that the quality of geometric knowledge that students developed had a strong effect on students' mental models [11]. The other research explored the role of software in solving geometry problems and how this software manipulated the process of problem solving. The results of this study indicated that the used software not only built the process of finding answers but also helped students to move from argumentation to logical deduction [12]. The last research conducted research in 2014 on improving the ability of problem solving geometries through cooperative learning based on Van Hiele's theory. The results of this study indicated that the improvement of problem solving skills in the experimental class was better than the control class [13].

Based on this background, this researcher conducted research on "Level of Student Understanding in Solving Geometry Problems Based on Taxonomy of SOLO (Structure of Observed Learning Outcomes)". The purpose of this study is to determine the level of understanding of students in solving problems in the geometry of planes and spaces and classifying the level of understanding.

2. Methods
The results of this research data in the form of numbers had been obtained from student answer sheets. Then, the interview data which were complementary to the data from the answer sheets would be presented in accordance with the events that occurred in research. The data analysis was carried out in inductive perception. In accordance with the characteristics stated above, the research approach used a qualitative approach. The characteristics of the qualitative approach were namely: (1) the researcher acted as the main instrument, because besides being a data collector and analyst, the researcher was also directly involved in the research process, (2) had a scientific background (natural setting), the studied and generated data would be presented in accordance with what happened in the field, (3) the results of the study were descriptive, (4) more concerned with the process rather than the results, (5) the limitation of the problems specified in research focus, and (6) data analysis tended to be inductive [14]. Data collected in this study were generally in the form of verbal data, so this type of research was a descriptive exploratory qualitative research.

This research was conducted on students who took courses in geometry. The subjects of this study were 35 students. To obtain data, this study used instruments, namely: researchers, recording equipment, and task sheets. In this qualitative research, the main instrument was the researcher himself or others who help the researcher. Data collection was done by giving the proof problems to students. In the process of solving these problems, students were asked to express what they thought when solving problems. Then the researcher recorded the student's verbal expression. After finishing with one student, the same process would be carried out on other students who were the research objects that have been predetermined. Such data collection belonged to the Think-Aloud method [15]. This research data
collection place was carried out on campus or elsewhere that allowed research subjects to feel comfortable and to be creative.

The process of data analysis in this study was carried out by the steps: (1) conducting data reduction, namely selecting, focusing and classifying similar data, then simplifying with removing unnecessary things, (2) presenting data, (3) drawing a conclusion. This referred to the flow model data analysis technique [16].

3. Results and discussion
This research was conducted to see the level of understanding of students in solving geometry problems based on the SOLO (Structure of Observed Learning Outcomes) taxonomy. A recap of the level of student responses in solving the geometry problems is shown in table 1 below.

| Level         | Problem 1 | Problem 2 | Problem 3 | Total of Responses | Percentage |
|---------------|-----------|-----------|-----------|--------------------|------------|
|               | n         | n         | n         |                   |            |
| Prestructural | 0         | 1         | 0         | 1                  | 1%         |
| Unistructural | 3         | 8         | 30        | 41                 | 39%        |
| Multistructural | 27       | 26        | 5         | 58                 | 55%        |
| Relational    | 5         | 0         | 0         | 5                  | 5%         |
| In Total      | 35        | 35        | 35        | 105                | 100%       |

Note: n = total of students

Based on the table 1, it can be seen that the distribution of students’ level of understanding for questions number one were the unistructural, multistructural, and relational levels, for questions number two at the prestructural, unistructural, and multistructural levels. As for problem 3, the students understanding were at the unistructural and multistructural level. The following discussion breakdown samples at each level.

3.1. Prestructural level
At this level there was only one response represented by S1.

From the Figure 1, it appeared that S1 was still not right in placing the position of the letter at the corner point of a cube. This caused S1 misplaced the positions of the letters P and Q. However, the rectangular shape made by S1 remained the same size and shape as the shape referred to the problem. S1 could not calculate the area of the quadrilateral. S1 also could not determine the length of the sides of the rectangle. S1 did not have the knowledge or skills to calculate the lengths of the sides of the rectangle. Therefore S1 could not determine the area of the rectangle in question.
Students with responses like these are included in the prestructural level. Students at the level of prestructural reasoning cannot make decisions (cannot provide answers) [7]. Student responses indicator that are at the prestructural level is not had the skills to solve problems [17].

3.2. Unistructural level
At this level students only used one concept that was right. Forty one of responses were at this level. As in problem 1, S2 was right to use the concept of distance to calculate the shortest path. However, S2 was still wrong in understanding the problem, namely the path of AIJKLH was not the distance between points A and K. Likewise with S3 to calculate the square area of DPQF (problem 2), S3 was correct in calculating the lengths of the sides of the rectangle.

![Figure 2. Answer sheet of S3.](image)

From the Figure 2, S3 had also correctly used the concept of a right triangle so that the Pythagorean principle applied. S3 had correctly calculated the length of the PF side. Whereas S4 used the concept of congruence to calculate the GH side length. S4 was correct in using the congruence concept if the length of the BH side was known.

At this level, each subject had used a correct concept to answer the given problem. The unistructural level indicator is that students only use one relevant aspect [8]. The other student response indicator at the unistructural level is that students only use at least one clue and one concept or process of solving [17].

3.3. Multistructural level
Total responses at this level were 58 responses. At this level students had used several appropriate concepts. As in problem 1, S6 had understood the problem correctly. This could be seen from the count done by S6.
Figure 3. Answer sheet of S6.

From Figure 3, S6 was correct in using the Pythagorean concept, as well as the sum of quadratic forms and root withdrawals. Then S6 had tried to connect between concepts, namely the relationship between rectangles that had the same side length with a square. According to S6 the rectangle was square because the four sides were the same length and the sides were located in the perpendicular plane. But this relationship was not right because besides the square there was still a rhombus that had the characteristics of all four sides of the same length.

At this level the subjects use some correct information or concepts, and try to link them. Therefore subjects with such indicators are at the multistructural level. The students that are at the multistructural level can make some relationships from some data or information, but the relationships are not right so the obtained conclusions are not relevant [17].

3.4. Relational level
At this level students had used several appropriate concepts. Total responses at this level reached 5 from 105. One of the responses was done by S8.

Figure 4. Answer sheet of S8.

From Figure 4, S8 was right in using the concept of distance, calculating distance by using the Pythagorean concept, summing up squares and then taking root. Then S8 also correctly positioned the points J, K and L so that S8 got the same distance between JK and LH. However, S8 experienced a slight mistake in determining the shortest path. The shortest path would be obtained if the distance between AI was equal to JK and LH. Whereas S8 only made JK = LH. But this answer already approached the requested answer. The students with such response indicator enter the relational level [17].
4. Conclusion
Based on the results and discussion, it can be concluded that in solving the given geometry problems, the level of understanding of students varied from the prestructural to the relational level. The order of levels that had the most responses was multistructural level – unistructural level – relational level – prestructural level.

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