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How is the PISA-Like Problem-solving Skills Level 1 to Level 3 of Junior High School Students?
Analysis Based on SOLO Taxonomy and Gender Difference

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ABSTRACT
Problem-solving ability is one of the important competencies for every individual. However, PISA results show that Indonesian students' mathematical problem-solving abilities are still low. The mathematical literacy contest which was expected to improve the problem-solving ability of Indonesian students at PISA did not produce good results. This is the background for conducting this research. The purpose of this study was to determine students' ability to solve PISA-like problems level 1 to level 3 based on SOLO taxonomy and gender differences. The research was conducted in State Junior High School 2 Baki. Using purposive sampling, 1 male student and 1 female student in class VIIIF were selected as research subjects. Data collection using test and interview. The data were analyzed using the Miles and Huberman technique. Triangulation method is used to determine the validity of the data. The results showed that at level 1, the PISA-like problem-solving abilities of both male and female students were at the Uni-Structural level; at level 2, the abilities of male students were at the Pre-structural level while female students were at the Multistructural level; and at level 3 both male and female students were at the Pre-Structural level.

Keywords: *Gender, PISA-like, Problem-solving, SOLO taxonomy.*

1. INTRODUCTION

Problem-solving ability is one of the most important skills for every individual in all corners of the world. This was revealed by the Assessment and Teaching for 21st century skills which explained that there are four main things in 21st century skills, namely ways of thinking, ways of working, work tools and life skills. The way of thinking here includes creativity, critical thinking, problem-solving, decision making and learning [1]. [2] also explains that the ability to think and solve problems which consists of the ability to think critically, laterally, and systematically, especially in the context of problem-solving is one of the skill competencies that must be possessed by each individual. Through education and teaching in schools, it is expected to be able to develop these problem-solving abilities. The results of the study [3] show that 100% of practitioners and experts agree that the importance of providing problem-solving skills to students for their future life.

Mathematics is one of the subjects given at every level of formal education in Indonesia. One of the content of mathematics subjects taught at the secondary school level is showing a logical, critical, analytical, careful, thorough, responsible, responsive, and not easy to give up attitude in solving problems [4]. The same thing is explained by [5] that problem-solving provides a relationship between facts and algorithms with real-life problem situations that we all face, so that by learning mathematics it is hoped that students can learn how to successfully solve a problem.

PISA organized by the OECD is one of the activities with the aim of knowing students' problem-solving abilities in the domains of science, mathematics, and reading. This activity is carried out

every three years where in each implementation, the ability of Indonesian students, especially in the mathematics domain, always shows low results. In 2011, the Ministry of Education and Culture of the Republic of Indonesia appointed an Indonesian Realistic Mathematics Education Team to carry out mathematical literacy contest activities with the aim of socializing questions in accordance with the PISA focus to students. The contest is expected to develop the ability of Indonesian students in solving math problems according to the focus of PISA [6]. Based on [7], one of the factors in the development of the 2013 curriculum (the curriculum currently used in Indonesia) is the unhappy achievement of Indonesian students in some editions of PISA and many materials on PISA that are not in the previous curriculum However, these two efforts have not been able to boost the achievements of Indonesian students in PISA.

The latest PISA report in 2018 showed that 28% of Indonesian students could only reach level 2 or more and only 1% of Indonesian students were able to reach level 5 or more [8]. Based on the results of PISA in 2018, the research was limited to PISA level 1 to level 3. Students' abilities in the mathematics domain at PISA consist of 6 levels where level 1 is the lowest level and level 6 is the highest level. Each of these levels has a description of the skills that students can perform and achieve [9].

Stage 1, at this level students are able to solve problems that are familiar and related to real-life contexts by identifying information and using solving steps that they routinely use.

level 2, at this level students are able to solve problems that do not require more than direct conclusions by using formulas, algorithms, and basic procedures to then make interpretations of the results. Students are also able to interpret, recognize situations, extract information from problems, and use single representation methods.

level 3, students are able to solve problems using simple problem-solving steps and have been given clearly before. The written solutions show students have been involved in basic interpretation and reasoning. Students are able to interpret from different sources of information. students are able to work with percentages, fractions, decimal numbers, and proportional relationships.

Gender is one of the factors that can help in distributing mathematical literacy skills to the entire population in a country [10]. Furthermore, gender can also affect the variability of cognitive and non-cognitive outcomes in schools and the gap between high-achieving students and low-achieving students.

Keitel (1998) in [11] explains that gender, social and cultural dimensions are very strongly interacting in the conceptualization of mathematics education. [12] explained that gender equality was the most consistent condition in influencing the 2015 PISA results. [13] also explains that gender has a significant impact on students' performance in school. Zhu (2007) in [14] explains that there are factors of gender differences in students' mathematical problem-solving abilities. Some of these opinions indicate that there are factors of gender differences that affect problem-solving abilities and student performance in school. Therefore, in this study, the aim of this study was to determine the mathematical problem-solving ability of PISA-like male students and female students.

The level of competence in the 2013 curriculum is based on the taxonomy of the structure of observed learning outcomes (SOLO taxonomy) [7] where this taxonomy examines the thinking processes used by students to reach answers and focuses on the answers given by students [15]. SOLO taxonomy can also be used to determine students' mathematical thinking skills and understanding of a concept in mathematics [16]. [17] argues that this taxonomy is suitable for measuring learning outcomes of all subjects, levels, and all types of tasks. Furthermore, [18] states that the SOLO taxonomy provides a systematic way to describe a student's performance when studying and/or completing assignments, especially tasks performed at school. Based on several opinions related to the SOLO taxonomy, it appears that this taxonomy can be used to examine the thinking processes and mathematical thinking abilities of students. In addition, this taxonomy can also be used for PISA-like math problems. Therefore, in this study the SOLO taxonomy is used as the basis of analysis to determine and describe the level of thinking processes and students' abilities in solving PISA-like math problems.

The SOLO taxonomy consists of five levels namely Pre-structural, Uni-structural, multistructural, relational, and extend abstract [15], [18]–[20].

Pre-structural. At this first level, students do not really have prior knowledge to help them in understanding a topic. For example, students may provide data and information that is completely irrelevant to the topic, students may not have the appropriate skills to complete a given task, students may not understand the question. At this level students also give answers that have absolutely nothing to do with the problem to be solved.

Uni-structural. At this level students have limited knowledge about a topic. For example, students may apply ideas and problem-solving steps that they have memorized previously but the results and conclusions obtained are irrelevant. Students are also possible to use at least one information and problem-solving steps. In addition, at this level, students are able to use terminology, perform simple instructions/algorithms, identify information, and perform calculations.

Multistructural. At this level, students already have knowledge of some facts about a topic but they have not been able to relate them. The answers given by students can provide some relevant facts, are able to correctly identify the characteristics of a phenomenon, but the facts that are known by these students are not related to each other so the results obtained are irrelevant. At this level, students are able to perform calculations, represent problems in the form of pictures, classify information, apply a method, and carry out problem-solving steps.

Relational. At this level, students are able to connect known information together and are able to explain several ideas related to the topic requested from the problem. For example, students are able to connect known pieces of information to get a suitable solution for a task. The answers given by students also show clear relationships and relevant details. Students are also possible to express their answers in abstract ideas with concrete facts. At this level, students are able to work with comparisons, relate their knowledge, conduct analysis, and apply the theory they know.

Extend Abstract. At this level students are able to connect many ideas at once with a larger concept through reflection and evaluation. For example, students can derive general principles from integrated data and be able to apply them to new situations. Students' answers show that students are able to apply reasoning, make many connections, and combine/design principles from their knowledge to be applied to new situations.

This research is preliminary research. The purpose of this study was to determine the PISA-like problem-solving abilities of level 1, level 2, and level 3 of male and female students based on the SOLO taxonomy.

2. METHODOLOGY

This is qualitative-descriptive research with a case study method. Cohen, Manion, & Morrison (2000) in [16] explain that the case study method allows searching in selected subjects in detail. In addition, this method can be used to get answers to how and why questions. This research was conducted in class 8F of Baki 2 Junior High School, Sukoharjo Regency, Indonesia. The class consisted of 18 male students and 13 female students. The researcher is the main instrument in this study, then written tests and interviews are used as supporting instruments. The written test was followed by 31 students of class 8F in the form of essay questions. Purposive sampling technique was used to select 1 male student and 1 female student as research subjects for later interviews. The selected students are students who have taken a written test and are a recommendation from the teacher where the selected students have good academic abilities and are able to express their ideas when interviewed. The data analysis technique adopts the Miles and Huberman technique which consists of data collection, data reduction, data presentation and drawing conclusions. To determine the validity of the data, a triangulation method was used between written tests and interviews

Kak ros has just bought a new bunk bed for Upin and Ipin as in the picture.

When measured by Kak Ros, it turns out that the height of the bed is 1.5 meters and the length of the stairs is 1.7 meters.

Determine the distance from the bottom of the bed to the bottom of the stairs!

Note :

1. Write down the information that is known from the question
2. Write down the problem to be solved from the question
3. Write down the steps to solve the problem of the question

Figure 1 Question number 1 with PISA level 1

3. RESULTS AND DISCUSSION

The test questions in this study consisted of three questions which were arranged based on the description of the students' level of mathematical proficiency in PISA. Item number 1 with PISA level 1, item number 2 with PISA level 2, and item number 3 with PISA level 3. The questions that have been prepared are then submitted to two mathematics education lecturers to test the validity of the items. The result is that the items that have been compiled on the test instrument are valid and suitable to be used for data collection.

3.1. PISA Level 1 (Question Number 1)

The problem for question number 1 with PISA level 1 is as shown in Figure 1.

3.1.1. Male Student Ability

The male student's answer to question number 1 is shown in the following Figure 2

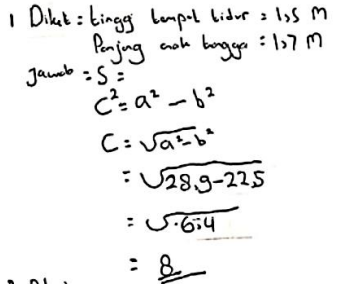


Figure 2 Male student answer to question number 1

Figure 2 shows that male students are able to write down the information contained in the questions (see *diket*). However, students do not write down what problems must be solved from the question. From Figure 2 it also appears that students are able to use the Pythagorean method (see *jawab*). However, there are some parts that are not perfect from using the Pythagorean method. For example, the student does not mention the meaning of his writing a, b, and c. In addition, students also miscalculated and did not write down the conclusions from the questions.

The transcript of the interview with male students for question number 1 is as follows.

Researcher	:	*"Can you mention any information that is known from question number 1?"*
Male Student	:	*"The information that can be known from the question is that the height of the bed is 1.5 meters and the length of the stairs is 1.7 meters. Then asked to determine the distance between the feet of the bed and the feet of the stairs"*
Researcher	:	*"After you know that information, then how do you solve question number 1?"*
Male Student	:	*"Question number 1 uses the Pythagorean formula. The length of the ladder is squared first, then subtracted by the height of the bed. Finally, the result of the subtraction is rooted"*
Researcher	:	*"Why did you choose to use the Pythagorean formula?"*
Male Student	:	*"Because I've done this kind of question before."*

From the interview, it is known that students are able to mention the information that is known and the problems that must be solved from question number 1. Students are also able to apply the Pythagorean formula to solve question number 1. This is because students have already worked on the same type of question as question number 1.

3.1.2. Female Student Ability

The female students' answers to question number 1 are as shown in Figure 3 below.

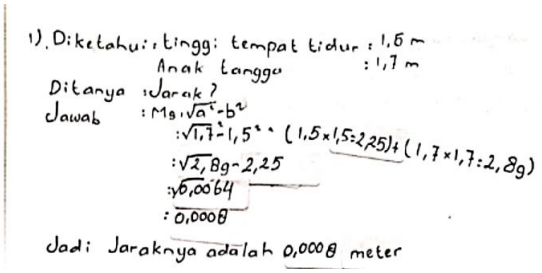


Figure 3 Female student answer to question number 1

Figure 3 shows that student are able to write down the information that is known from the question (see *diket*) and also able to write down the problems to be solved in the questions (see *ditanya*). Not much different from the answers from male students (see Figure 2), female students also use the Pythagorean method to solve questions (see *jawab*). However, it appears that the students did not mention the meaning of a, b, and Ms that she wrote down. The student also miscalculated so the results he wrote were also wrong. As a result, the conclusions written by students are also wrong.

Vending Machine is an automatic vending machine that can be used to sell daily necessities. 2017 data shows that Japan is the country with the most vending machines in the world.

Soft drinks and snacks are necessities that are often found in vending machines. The way the vending machine works is to put some money in the hole provided then the food or drink will come out by itself

When you enter 900 yen, two cans of drinks and five packs of food will come out, then when you enter 1000 yen, three cans of drinks and four packets of food come out. To get six cans of drinks and six packs of snacks, how much money must be put in the vending machine?

Note :

1. Write down the information that is known from the question
2. Write down the problem to be solved from the question
3. Write down the steps to solve the problem of the question

Figure 4 Question number 2 with PISA level 2

The transcript of the interview with female students for question number 1 is as follows

Researcher	:	*"What information is known from question number 1 ?"*
Female Student	:	*"1.5 meters high bed and 1.7 meters long stairs"*
Researcher	:	*"Then what is the problem that must be solved from question number 1? ?"*
Female Student	:	*"We are asked to determine the distance between the bottom of the bed and the bottom of the stairs"*
Researcher	:	*"How do you determine the distance ?"*
Female Student	:	*"I use the Pythagorean method. Root of a squared minus b squared"*
Researcher	:	*"What do the a and b you mentioned earlier mean ?"*
Female Student	:	*"a means the length of the stairs, then b means the height of the bed"*
Researcher	:	*"Why did you choose to use the Pythagorean formula ?"*
Female Student	:	*"In the past, the teacher had explained about Pythagoras. He also once gave practice questions where the questions in the practice questions were similar to this one"*

Based on the interviews, it appears that female students are able to mention the information that is known and the problems that must be solved from question number 1. Students are also able to explain the solution steps that she used. Same with male students, the reason for female students using the Pythagorean formula is because she has previously worked on similar problems.

3.2. PISA Level 2 (Question Number 2)

The problem for question number 2 with PISA level 2 is as shown in Figure 4.

3.2.1. Male Student Ability

The male student's answer to question number 2 is shown in the following Figure 5

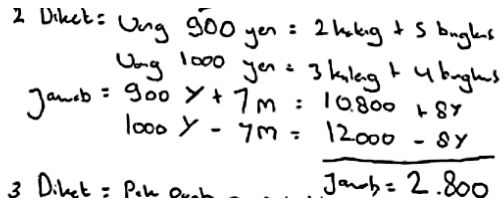


Figure 5 Male student answer to question number 2

Figure 5 shows that male students are able to write down the information that is known from the questions (see *diket*). Just like when working on question number 1 (see Figure 2), students do not write down the problems that must be solved. When students try to solve question number 2 (see *jawab*), it appears that students make mistakes when converting the problem into mathematical form. This results in errors in calculations and the final result is also wrong. Students also do not write the final conclusion.

The transcript of the interview with male students for question number 2 is as follows.

Researcher	:	*"For question number 2, what information can you find out and what problems must be solved"*
Male Student	:	*"When we enter 900 yen, we get 2 cans of drinks and 5 packs of food. When you enter 1000 yen, you will get 3 cans of drinks and 4 packs of food. we are asked to determine the money that must be entered to get 6 cans of drinks and 6 packs of food"*
Researcher	:	*"In your opinion, how do you solve this problem?"*
Male Student	:	*"I changed it to a mathematical form with an illustration"*
Researcher	:	*"What is the form of the illustration?"*
Male Student	:	*"The form of the example I use is 900y + 7m = 10.800 + y and 1000y - 7m = 12.000 - 8y. Then both I eliminate or reduce"*
Researcher	:	*"Where did you get this illustration from?"*
Male Student	:	*"I know that question number 2 is solved using a two-variable linear equation system, but I don't know how to solve it. So I write what it is, like the form of the previous illustration"*

From the interview, it can be seen that male students actually know the methods that can be used to solve problems. However, he doesn't know the steps to use that method. So, he only answered as is when solving the problem in question number 2.

3.2.2. Male Student Ability

The female student's answer to question number 2 is shown in the following Figure 6

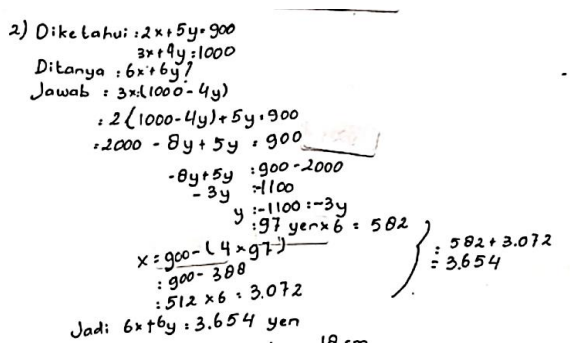


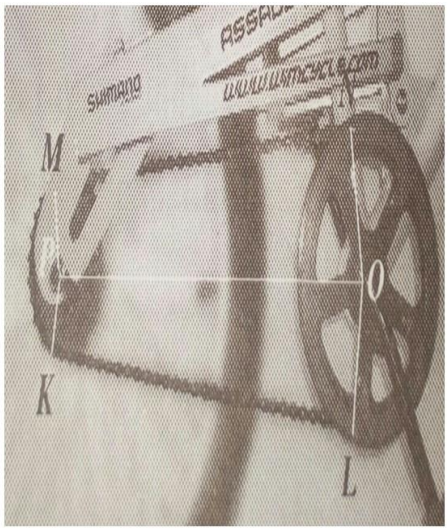
Figure 6 Male student answer to question number 2

Figure 6 shows that female students are able to write down any information she knows from the questions (see *diketahui*) and be able to write down what problems need to be solved (see *ditanya*). It seems that the female student uses the illustration "x" and "y", but she doesn't write down the meaning of the illustration. When answering question number 2 (see *jawab*), she tried to use the substitution method, but she miscalculated. So that the results obtained were not appropriate and the conclusions she wrote were wrong.

The transcript of the interview with female students for question number 2 is as follows.

Researcher	:	*"For question number 2, what information is known and what problems must be solved?"*
Female Student	:	*"The information that is known from question number 2 is that when you enter 900 yen, you get 2 drinks and 5 food. When you add 1000 yen, you get 3 drinks and 4 food. Then the problem is being told to determine the money that must be entered to get 6 drinks and 6 food."*
Researcher	:	*"How to solve this problem?"*
Female Student	:	*"I use the substitution method"*
Researcher	:	*"Please explain the substitution method"*
Female Student	:	*"we illustrate with x and y, then substitute"*
Researcher	:	*"what do x and y mean?"*
Female Student	:	*"x is an illustration for drinks and y an illustration for food, then we calculate it using the substitution method"*
Researcher	:	*"is there any other way besides the substitution method"*
Female Student	:	*"I thought there was another way, but I forgot"*

Based on the interview, it appears that the female students understand at least one of the methods that can be used to solve the problem in question number 2



Bicycles are an environmentally friendly means of transportation and are currently widely used in Indonesia. One of the important components on a bicycle is the gear and chain to move the bicycle.

Mr. Ogah is a mechanic in a bicycle repair shop. One day, Mr. Ogah was in charge of repairing a broken bicycle chain. The diameter of the front gear of the bicycle is 18 and the diameter of the rear gear is 2/3 of the diameter of the front gear. The distance between the two gear axes is 50 cm and $\angle LON = 150°$. Determine the chain length of the bicycle repaired by Mr. Andi!

Note :

1. Write down the information that is known from the question
2. Write down the problem to be solved from the question
3. Write down the steps to solve the problem of the question

Figure 7 Question number 3 with PISA level 3

3.3. PISA Level 3 (Question Number 3)

The problem for question number 3 with PISA level 3 is as shown in Figure 7.

3.3.1. Male Student Ability

The male student's answer to question number 3 is shown in the following Figure 8

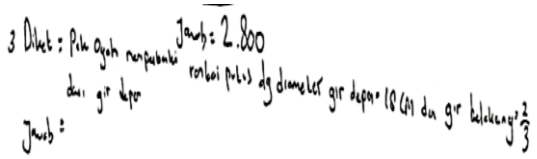


Figure 8 Male student answer to question number 3

Figure 8 shows that male students are able to write down the information that is known from the questions (see *diket*) although the information written does not include all the information in the question. In question number 3, students also do not write down what problems must be solved. In addition, students also did not try to solve question number 3 (see *jawab*). This implies that male students are not able to solve the problem in question number 3.

The transcript of the interview with male students for question number 3 is as follows.

Researcher	:	*"try to mention what information is known in question number 3"*
Male Student	:	*"The front gear is 18 cm in diameter, the rear gear is 2/3 the diameter of the front gear. The distance between the front gear and the rear gear is 50 cm and the LON angle is 150 degrees"*
Researcher	:	*"what is the problem to be solved?"*
Male Student	:	*"What is the length of the bicycle chain?"*
Researcher	:	*"How to solve it?"*
Male Student	:	*"I don't understand at all"*

From the interview it appears that the male students do not understand at all how to solve the problem in question number 3

3.3.2. Female Student Ability

The female student's answer to question number 3 is shown in the following Figure 9

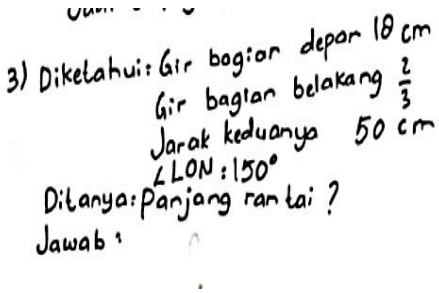


Figure 9 Female student answer to question number 3

Figure 9 shows that students are able to write down the information that is known from the question (see *diketahui*) and are able to write down the problems that must be solved from the question (see *ditanya*). But she didn't try to solve the problem (see *jawab*).

The transcript of the interview with female students for question number 3 is as follows.

Researcher	:	*"What information is known from question number 3?"*
Female Student	:	*"The diameter of the front bicycle gear is 18 cm, while the rear is 2/3 of the diameter of the front gear. The distance between the two gears is 50 cm and the LON angle is 150 degrees"*
Researcher	:	*"How to get the length of a bicycle chain?"*
Female Student	:	*"I don't know at all how to do it"*

Based on the interviews, it appears that female students also do not know how to solve the problems in question number 3 and have difficulty understanding the question.

Based on the analysis results from written tests and interviews, then it is used to determine the problem-solving abilities of PISA-like level 1, level 2, and level 3 of male and female students. At PISA level 1, the results of the analysis of answers and interviews of male students (see 3.1.1) and the results of analysis of answers and interviews of female students (see 3.1.2) show that both male and female students are able to show the correct information. known from the question. Both of them are also able to show the problem to be solved, but the male students don't write it down on the test. When answering questions, both are able to write down and show steps to apply appropriate methods to solve problems. However, both of them were wrong in the calculation, so the results obtained were not compatible. Therefore, both male and female students are at the Uni-Structural level of the SOLO taxonomy for PISA level 1.

At PISA level 2, the results of analysis of test answers and interviews from male students (see 3.2.1) can be seen that student actually know the material that can be used, but he does not know how to solve the problem. So that male students only write what is when doing the test. Therefore, the ability of male students is at the pre-Structural level of the SOLO taxonomy at PISA level 2. Meanwhile, the results of analysis of test answers and interviews from female students (see 3.2.2) show that she understands the methods that can be used to solve problems. She also uses illustrations using "x" and "y" to help in solving problems. However, she miscalculated, so the results were not appropriate. Therefore, the ability of female students is at the Multistructural level of the SOLO taxonomy at PISA level 2. This finding is in accordance with the results of research from [21] which shows that at the pre-Structural level students, students are not able to process information well, problem-solving steps written down have no meaning, and have a tendency not to give relevant results with problems to solve. While students with the Multistructural level, students understand at least one concept to solve problems, are able to do illustrations with other variables and are able to change the problem into a more mathematical form. However, the results given by students are not appropriate. Laisouw in [22] also said that students at the multistructural level, they are able to carry out algebraic thinking processes which include the ability to carry out investigations, representations, and generalizations well.

At PISA level 3, the results of analysis of test answers and interviews of male students (see 3.3.1) and results of analysis of test answers and interviews of female students (see 3.3.2) show that both male and female students are able to name information that is known and the problem to be solved in the question. Even though the male students didn't completely write it down during the test. In addition, it can be seen that both male and female students do not understand the problem in question number 3. So they are not able to solve the problem. Therefore, the abilities of both male and female students are at the pre-Structural level of the SOLO taxonomy at PISA level 3. The findings in this study which show that at PISA level 1, students' problem-solving abilities are at the Uni-Structural level of the SOLO taxonomy in accordance with the opinion [23]. The same applies to level 2, where students' abilities are at the Multistructural level, although in this study only female students were able to achieve it. Then, at level 3, the findings in this study show that students' abilities are at the pre-Structural level, this is contrary to [23] which states that at level 3 students' abilities are at the Relational level.

It also appears that female students write down their test work in sequence starting from writing down the information that is known to then the problems that must be solved. When answering questions, female students also tried to write down the steps to solve the problem neatly and coherently. This is in contrast to male students who tend to be untidy and in a hurry to solve problems from questions. For example, the incompleteness of male students in writing down known information (see Figure 8), not writing down the problems to be solved, and not in order in writing the problem-solving steps (see Figure 5). However, both of them have something in common, namely the tendency to be less precise in calculations so that the answers given are not appropriate. This finding is in

accordance with the findings of [24] which states that on average female students are neater in writing processes and stages of problem-solving so that it can be said that female students are more systematic than male students. The habit of male students who are not systematic in writing often causes them to have difficulty in the process of solving problems on math questions. In 3.2.1 it also appears that the male student wrote the answer as it was when he did not understand how to solve the problem. This finding is in line with the explanation from Krutetzkii (1976) in [25] that male students tend to be less thorough and rush to solve a problem briefly, especially in the thinking process.

4. CONCLUSION

Based on the explanation in the Result and Discussion section, the conclusions of this study are (1) at PISA level 1, the problem-solving abilities of both male and female students are at the Uni-Structural level, (2) At PISA level 2, the problem-solving abilities of male students are at the Pre-Structural level, while the problem-solving abilities of female students are at the Multistructural level, and (3) at PISA level 3, the problem-solving abilities of both male and female students are at the Pre-Structural level. Furthermore, when carrying out the process and stages of problem-solving, female students are more systematic than male students.

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