Analysis of Students Algebraic Reasoning Levels in Solving PISA Model Problems in View of Adversity Quotient

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Abstract: This research aims to describe students' level of algebraic reasoning based on the adversity quotient types of climber, camper, and quitter in solving PISA model mathematics problems. This research is descriptive research with a qualitative approach. The research began by administering a questionnaire to determine the student's adversity quotient type. After obtaining research subjects consisting of 3 climber-type students, 2 camper-type students, and 3 quitter-type students, the research continued with giving a PISA model problem-solving test (TPM) with think-aloud commands, and interviews. The data obtained was transcribed and validated using triangulation methods and then analyzed based on algebraic reasoning level indicators consisting of levels 0-3. The research results show that students with different adversity quotients achieve different levels in solving PISA model problems. Climber-type students meet levels 1 and 2, camper-type students meet level 1, and quitter-type students meet level 0.

Keywords: Level of Algebraic Reasoning, PISA Model Questions, Adversity Quotient

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Introduction

Mathematics has a crucial role in developing a person's thinking and reasoning skills, so it becomes an integral part of the curriculum at all levels of education, from elementary school to college. Mathematics consists of several branches, one of the branches that must be mastered by students is Algebra. Algebra is a branch of mathematics concerned with the way we express generalizations about numbers, quantities, relations, and functions (Watson, 2010). This is supported by the statement that Algebra is a collection of concepts, ways of thinking, and skills that allow students to generalize, model, and analyze mathematical situations (NCTM, 2000). Thus, it is important to master algebra as a basis for generalizing related to mathematics.

The topic of algebra is related to abstract structures and the use of the principles of abstract structures in solving mathematical problems (NCTM, 2000). Algebra is said to be abstract about symbols, hence learning algebra requires the ability to understand symbols, their operations and rules (Andriani, 2015). The ability to understand symbols is explored in algebraic reasoning which contains the skills to understand patterns and make generalizations (Andriani, 2015; Ozturk, 2023). Algebraic reasoning is the generalization of mathematical ideas from a particular thing through argumentation and expressed formally according to the age of the student (Gardner & James, 1995). Algebraic reasoning is a type of reasoning used in solving algebraic problems (Blanton & Kaput, 2005). Thus, in algebraic reasoning, the ability to understand symbols plays an important role in recognizing mathematical patterns and making generalizations that enable students to apply their algebraic knowledge and skills effectively in a variety of mathematical contexts.

Algebraic reasoning has an important role to play in encouraging students of all ages to make guesses, devise rules, and generalize their learning (Ontario, 2012). In the process of drafting this rule, it should be noted that many students experience difficulties when they are faced with problems that have a different form from the one taught by the teacher (Bocro & Dapunto, 2007; Saglam & Akman, 2023). Most teachers are unaware of how students learn and master complex concepts, rules, procedures, or processes in mathematics (Thuneberg et al., 2018). Therefore, it is important to develop algebraic reasoning that can see structures in a variety of contexts, both in solving problems involving numbers or situations being modeled, as well as in the study of more general structures (Andriani, 2015). In algebraic reasoning, individuals can recognize patterns, relationships, and prevailing general principles, which helps them understand and solve math problems better.

The level of algebraic reasoning can be known through the process of solving problems. This statement is supported by NCTM which reveals that reasoning skills are needed when students are required to solve problems and draw conclusions in everyday life (NCTM, 2000). Problems occur when someone has a goal but does not know how to achieve it, while problem-solving is a process of student effort by using all the knowledge, skills, and understanding he has to find solutions to problems given or faced (OECD, 2013). Understanding different problems leads to different problem-solving. To measure and understand students' level of algebraic reasoning, it is important to provide them with problems that are often encountered in everyday life and have direct relevance to their lives. One type of question that meets this criterion is the PISA model question.

PISA itself focuses on students' ability to use their knowledge and skills in dealing with real-life challenges (OECD, 2013). By providing students with PISA model problems, it allows students to apply mathematical concepts in the context of everyday life so that they can see the relevance and usefulness of mathematics in real life. In addition, problem solving through PISA model questions can also help develop critical, analytical, and creative thinking skills, as well as improve students' ability to develop effective problem-solving strategies. Thus, the use of PISA model problems in algebraic reasoning research can provide a comprehensive picture of student's ability to solve mathematical problems contextually and see the extent to which students can apply algebraic reasoning in real-life situations.

The application of algebraic reasoning in solving problems needs to consider students' attitudes in facing challenges and difficulties that can affect students' motivation, confidence, and attitude toward problems. The ability of students to deal with problems and difficulties is commonly called the Adversity Quotient (Nada et al., 2020). The Adversity Quotient (AQ) is the intelligence that a person has when faced with a problem and is required to solve it (Stoltz, 2000). AQ is divided into three types, namely (1) climbers, a group of people who persistently try to reach the peak of success, (2) campers, a group of people who still have the desire to go through the challenges that exist, but do not reach the peak of success and are quickly satisfied with what is achieved, and (3) quitters, is a group of people who prefer to avoid and reject existing opportunities, easily discouraged, easily give up, and not eager to reach the peak of success (Stoltz, 2000).

Several studies discuss algebraic reasoning (Authary & Nazariah, 2019; Nuraini et al., 2016; Puspitasari, 2019), but there have been no studies that reveal the level of algebraic reasoning in solving PISA model problems in terms of adversity quotient. This research can provide a more comprehensive understanding of algebraic reasoning as well as insight into how resilient students are to difficulties and challenges in mathematics learning, especially in the context of algebraic reasoning. So that researchers are interested in examining "the level of algebraic reasoning of grade IX students in solving PISA model problems in terms of adversity quotient".

Method

This research is descriptive research with a qualitative approach that aims to describe the level of algebraic reasoning of students based on the adversity quotient type of climber, camper, and quitter in solving PISA model problems. The research instrument consists of adversity quotient questionnaires, PISA model problem-solving tests (TPM) with think-aloud commands, and interview guidelines. The instrument has been validated by 3 experts in the field of Mathematics and Psychology Education. The data obtained in the transcript is then analyzed based on the adaptation of algebraic reasoning level indicators (Ake et al., 2013) consisting of levels 0-3 including using known information, using patterns, appearing symbols, to making generalizations.

Table 1. Algebraic Reasoning Level Indicator

Algebraic Reasoning Indicator Code	Reasoning Levels	Algebraic Reasoning Indicators
L1	Level 0	Students can identify concrete examples of a pattern or situation but are unable to generalize. Students use a trial-and-error approach in solving problems without being able to formally explain or generalize

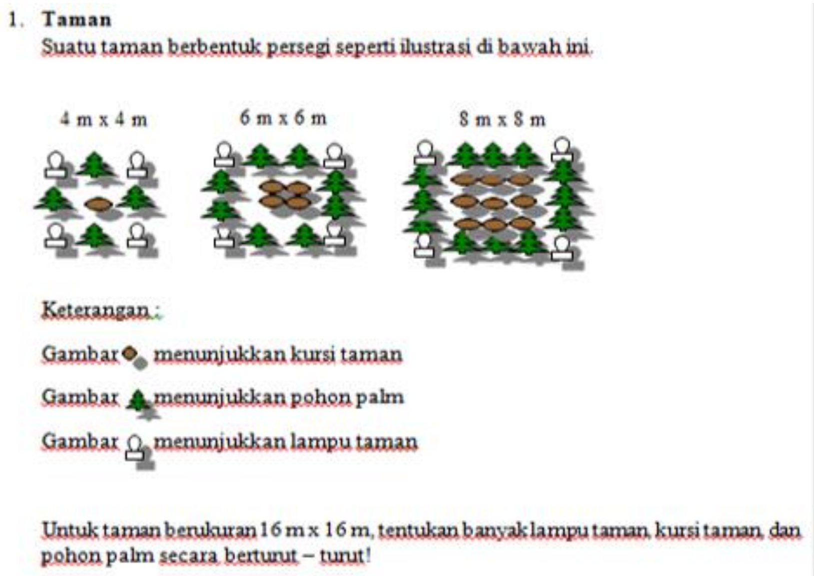
		concepts.
L2	Level 1	Students can identify more abstract patterns or situations and can make simple generalizations. They can identify relationships between variables and make generalizations based on the patterns they observe.
L3	Level 2	Students at this level can develop more complex generalizations and construct arguments to support their generalizations. They are able to formally explain the mathematical relationships between variables and use the language of algebra to interpret the patterns they observe.
L4	Level 3	Students are capable of very complex generalizations and can extend their generalizations to a variety of mathematical contexts. They are able to identify and apply abstract structural principles in solving more complex mathematical problems.

The subjects of the study were 8 students of grade IX MTsN 2 Malang City with climber, camper, and quitter categories. Determination of subjects is carried out by purpose sampling techniques, namely determining the class that will be the subject of research based on recommendations from teachers to obtain appropriate data. The first step of the researcher was to give an adversity quotient (AQ) questionnaire to 80 students in grades 9D and 9F MTsN 2 Malang City who had been recommended by the teacher through a google form, then the results of the questionnaire were analyzed and 3 climber type students, 2 camper type students, and 3 quitter type students were selected to be the subject of research. The determination of AQ categories based on ARP scores (Stoltz, 2000) is presented in the following table.

Table 2. AQ Category Score

Number	Score	Student Category
1.	166-200	Climber
2.	95-134	Camper
3.	0-59	Quitter

Selected students are asked to solve PISA model problems contained in individual problem-solving test sheets, write down the steps clearly accompanied by *think aloud* during the problem solving process recorded using a voice recording device.


1. **Taman**
Suatu taman berbentuk persegi seperti ilustrasi di bawah ini.

4 m x 4 m   6 m x 6 m   8 m x 8 m

Keterangan :

Gambar menunjukkan kursi taman

Gambar menunjukkan pohon palm

Gambar menunjukkan lampu taman

Untuk taman berukuran 16 m x 16 m, tentukan banyak lampu taman, kursi taman, dan pohon palm secara berturut – turut!

Figure 1. Problem-Solving Test Questions

After students take the test, it is followed by an interview. The interview included structured and open interviews regarding students' algebraic reasoning in solving PISA model problems. Structured interviews by the instruments that have been prepared, open interviews are interviews that can develop according to field conditions.

Checking the validity of data in this study uses triangulation methods by comparing data sources in the form of problem-solving test results, think-aloud results, and student interview results. It is said to be valid if the data source has many similarities. Valid data were analyzed to describe students' levels and characteristics of algebraic reasoning. The data analysis stage is carried out by examining all data which includes problem-solving test results, think-aloud results, and interview results. The data was analyzed following the steps taken by Miles & Huberman consisting of data reduction, data presentation, conclusion drawing, and data verification.

Results

This section presents the results and discusses the answers of each subject on the written test, think-aloud, and interview. Each subject was assigned the codes S1, S2, and S3 for three climber-type subjects, S4 and S5 for camper-type subjects, and S6, S7, and S8 for quitter-type subjects. The following is exposure to research results from research subjects.

Description of S1 Research Results

S1 can identify known information and use known information to resolve problems. This is shown in the following figure.

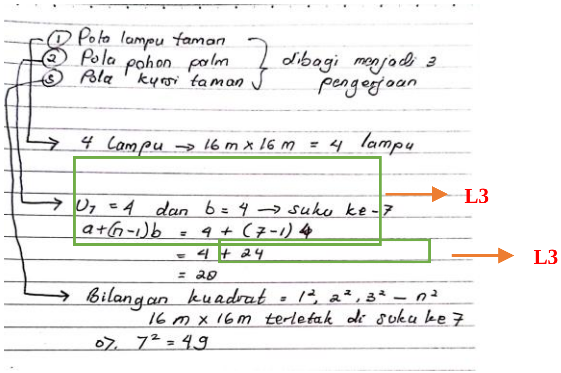


Figure 2. S1 Answer Sheet

Based on the answer sheet in figure 2, S1 finds many palm trees using the arithmetic sequence formula, namely. In addition, S1 writes the symbol n$a + (n-1)b^2$ to perform a square number example. The use of arithmetic sequence formulas and the example of quadratic numbers on this answer sheet shows that S1 is able to formally explain mathematical relationships between variables and use algebraic language to interpret the patterns they observe, this is reinforced by the following think-aloud results.

Think Aloud S1 Results

After looking for many lights, then looking for palm tree patterns, it can be seen that many trees form arithmetic rows with U1 = 4 and b = 4 (pause) then for a garden measuring 16 m x 16 m is the one, two, three, four, five, six, seven. So that the palm tree in the garden measuring 16 m x 16 m is a + (n-1)b, just enter into the formula obtained 4 + (7-1)4 = 4 + 24 = 28.

S1 strengthens the use of arithmetic sequence formulas by explaining the purpose of writing the symbols written on the answer sheet, this can be observed from the results of the following interview.

Q: "Try to explain the meaning of what you wrote, such as a, U1 and others."

S: "U1 is the first series of the problem, the above problem has several garden sizes, namely 4, 6, 8. Why is it called U1, called U1 because from these measures it can be seen from 4 to 6 has a difference of 2, likewise from 6 to 8 has a difference of 2, a is the initial term known from the above problem, meaning a is the earliest size of the garden on the left, while b is the difference or difference known from the question above, means B is known to have a difference of 2. Then n is the number of tribes. From the above questions asked is a size of 16 m x 16 m, then from the first series to 16 there are seven steps."

Description of S2 Research Results

S2 knows the information referred to by the question and states that in the question there is a square-shaped garden, this is shown by the following think aloud results.

I looked at the garden on this matter in the shape of a square, (paused) according to the garden size 4 m x 4 m, 6 m x 6 m, and also 8 m x 8 m, so the garden size 16 m x 16 m is square.

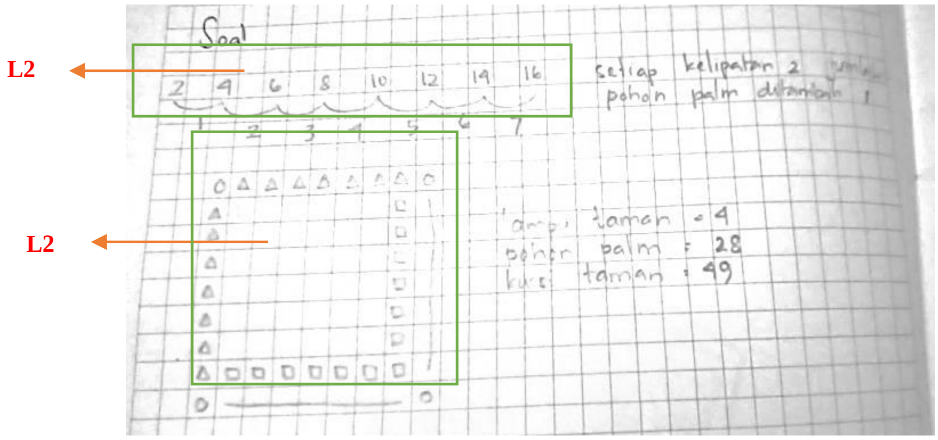


Figure 3. S2 Answer Sheet

Figure 3 shows that S2 performs a problem-solving process based on known information by drawing a pattern of multiples of two using symbols to determine the sequence of garden patterns measuring 16 m x 16 m. This is reinforced by the results of the following interview.

Q: "What do you mean by this pattern?"

S: "The meaning of the pattern, multiples of two ranging from 4 plus 2 to 16, after arriving at 16 plus one tree."

S: "Garden lights are circles, trees are triangular, chairs are squares."

Description of S3 Research Results

S3 writes known information on the answer sheet using symbols consisting of a square symbol to represent a chair, a triangle symbol to represent a tree, and a circle symbol to represent a lamp. This is according to figure 4 below.

The use of symbols in writing information known to S3 on the answer sheet is reinforced by the results of the following interview.

Q: "Do you use symbols in solving problems?"

S: "Yes sis, symbol of lights, trees, and chairs."

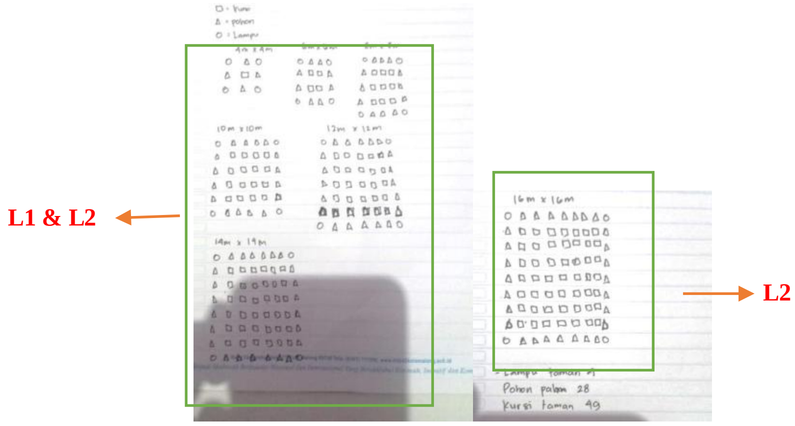


Figure 4. S3 Answer Sheet

The second step taken by S3 is to use known information to resolve the issue. S3 performs the problem solving process based on the garden sequence pattern, Here are the results of *think aloud* that supports S3 to solve the problem based on the garden sequence pattern.

Think Aloud S3 Results

The garden measuring 4 m x 4 m to the garden measuring 6 m x 6 m applies multiples of 2, judging from the brown picture in the garden measuring 4 m x 4 m the number is 1, then in the garden measuring 6 m x 6 m the number is to the right two to the left two so the sum is 4. Then in the garden the size of 8 m x 8 m is also the same, the brown picture applies multiples of 3 to the right and 3 to the left to 6. So we continue to draw the next park measuring 8 m x 8 m, 10 m x 10 m, 12 m x 12 m, 14 m x 14 m, and 16 m x 16 m.

Description of S4 Research Results

S4 solves the problem using a sequence of patterns, it can be seen when looking for many palm trees the subject writes the numbers 4, 8, 12, 16, 20, 24, and 28 where this number shows a sequence pattern of multiples of 4. In addition, in searching for many garden chairs, subjects wrote down the numbers 4, 9, 16, 25, 36, and 49 where this pattern is a sequence pattern of squared numbers.

S4 revealed that there is a pattern of multiples of odd numbers in the garden chair pattern, this is shown by the results of the following interview.

Q: "What do you understand from the problem?"

S: "Multiples of the same number, the number of garden chairs is 9 plus 5, then in add 7, and so on."

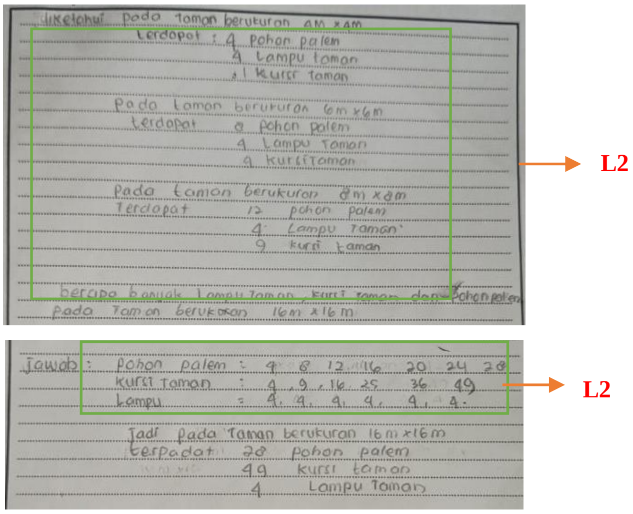


Figure 5. S4 Answer Sheet

The next step taken by S4 is to count many palm trees, garden chairs, and garden lights, each of which obtained 28 palm trees, 49 chairs, and 4 garden lights. Here's the S4 think aloud result showing lots of lights, trees, and garden chairs.

From calculations I get the results of 28 palm trees, 49 garden chairs, and at a garden size of 16 m x 16 m many lamps are 4 lamps.

Description of S5 Research Results

S5 writes down the known information on the subject's answer sheet in the form of writing symbols to represent lights, chairs, and palm trees, where the square symbol represents the chair, the circle symbol represents the lamp, and the triangle symbol represents the tree according to figure 6 below.

The use of symbols to represent garden lights, palm trees, and garden chairs in problem solving is reinforced by the results of the following interview.

Q: "Do you use symbols when doing problems?"

S: "Yes, the symbol is a circle, square, equal to a triangle."

The next step taken by S5 is to calculate the number of triangles, squares, and circles in a garden measuring 16 m x 16 m according to the question request. Based on calculations made by S5, 4 garden lights, 28 palm trees were obtained from the sum of trees around the park, and 49 garden chairs.

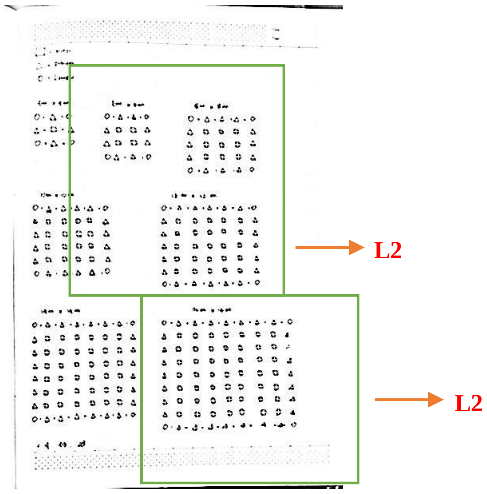


Figure 6. S5 Answer Sheet

Description of S6 Research Results

S6 does not write down the known information on the answer sheet according to Figure 7 below but goes directly to the problem-solving process of writing the perimeter of the square to find lots of garden lights, palm trees, and garden chairs.

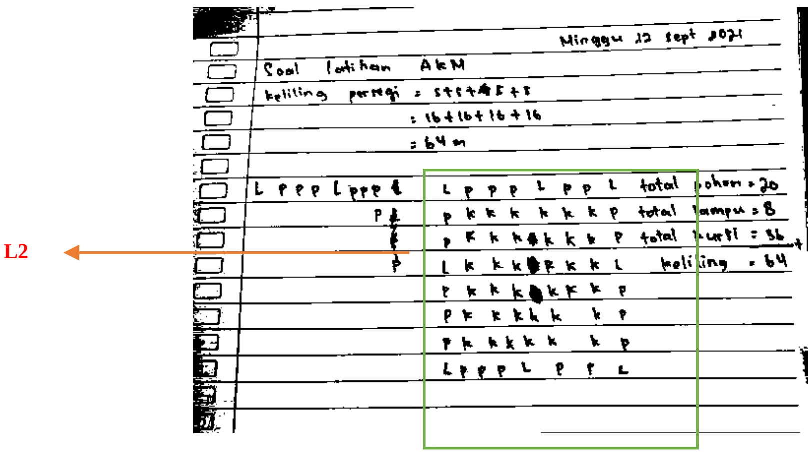


Figure 7. S6 Answer Sheet

Figure 7 shows that S6 lacks understanding of the command to search for lots of garden lights, palm trees, and garden chairs, as supported by the following interview.

Q: "What do you know from the question?"

S: "about lights, trees, and chairs."

Q: "How to solve it?”

S: " em.. (space) the number."

S6 does not understand the commands of the problem. In S6's understanding, the garden will be dark if the garden lights are only in the corner, so the S6 adds two lights to the garden where this does not fit the existing pattern. Here are the results of think-aloud S6.

Think Aloud S6 Results

There are 8 sides, meaning (silent) the arrangement must be 4, then if the size is 16 the arrangement must be 8. There are 8 trees, if there are only 4 lights it will be dark seats, so 2 lights are added on each side so that it does not get dark

S6's lack of understanding of the question commands can be seen from the results of the following interview.

Q: "Is there a pattern you use to solve the problem?"

S: "No sis."

Seeing S6's lack of understanding in troubleshooting results in S6 not being able to troubleshoot correctly.

Description of S7 Research Results

S7 looks for percentages in the troubleshooting process, this does not match the question command and indicates that S7 does not understand the known information and how it is solved. Here's the S7 answer sheet.

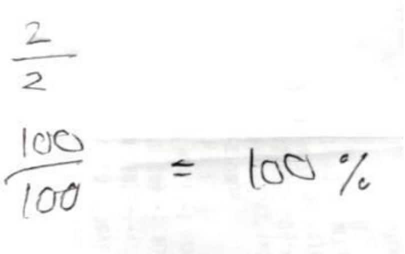


Figure 8. S7 Answer Sheet

S7 knows the command from the problem to find many lights, chairs, and palm trees, but S7 does not know how to solve the problem contained in the problem. This is shown by the results of the following interview.

Q: "After reading the questions, what information do you know from the questions?"

S: "There are lights, chairs, and some trees."

Q: "After that, what did you do to solve the problem?"

S: "I was confused at that time, and did not know what formula to use, I did it freely."

Description of S8 Research Results

S8 performs troubleshooting by using symbols and continuing patterns from the problem, the triangle symbol used for trees, the circle symbol for chairs, and the circle triangle symbol for lights. This is reinforced by the following *S8 think-aloud* results.

Think Aloud S8 Results

> I drew a picture first, in the size of a garden of 10 there are four trees down and four trees to the side, the seats follow the number of trees. In the garden size 12, there are 5 trees down and to the side, the picture of a chair following the tree. In garden size 14 there are 6 trees down and to the side, the image of a chair follows the tree. But for a while, I replaced the tree triangle, just this lampshade, the chair is a circle.

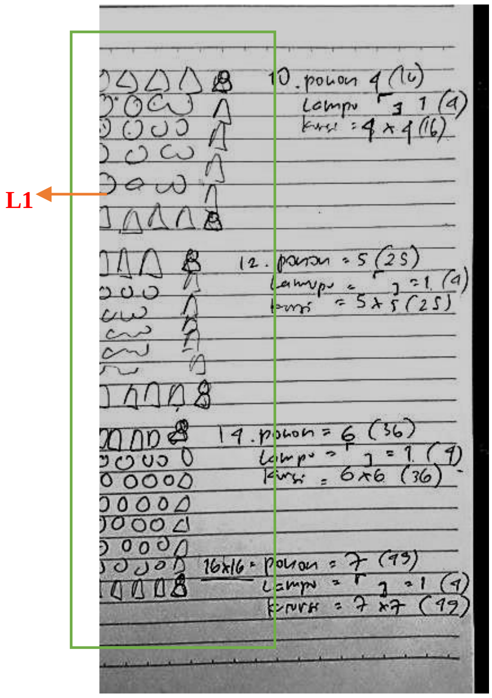


Figure 9. S8 Answer Sheet

As seen in Figure 9, S8 continues the pattern in the problem by drawing a garden using a triangle symbol to represent a tree, a triangle, and circle symbol to represent lights, and a circle symbol to represent a chair. The use of symbols for problem-solving is reinforced by the results of the following interview.

Q: "After knowing the information, what did you do to solve the problem?"

S: "I draw every number."

Q: "What kind of picture?"

S: "Picture like on my answer sheet."

After creating the symbol and continuing the problem pattern, the next step that S4 does is to count the number of lights, chairs, and trees based on the sequence of patterns according to the image that has been made. But the workaround done by S8 is not quite right.

Discussion

The following results summarize the levels and characteristics of student algebraic reasoning in solving the PISA model problems described above.

Table 3. Levels and Characteristics of Subject Algebraic Reasoning

Subject	Algebraic Reasoning Levels	Characteristics of Algebraic Reasoning
Climber	Level 1	Subjects are able to identify patterns, use symbols in solving problems, and make generalizations based on patterns that have been observed.
	Level 2	Subjects are able to identify patterns, use symbols to solve problems, and use algebraic language to interpret patterns that have been observed.
Camper	Level 1	Subjects are able to identify patterns, use symbols in solving problems, and make generalizations based on patterns that have been observed.
Quitted	Level 0	Understanding of the known information is still lacking, so problem solving is less precise.

Algebraic Reasoning Levels of Climber, Camper, and Quitter Type Students in Solving PISA Model Problems

The results showed that each subject with a different adversity quotient reached different levels in solving the PISA model problem. Three subjects with climber-type adversity quotients differed levels in solving PISA model problems, two subjects reached level 1, and one subject reached level 2. Two camper-type subjects in solving PISA model problems achieved level 1 algebraic reasoning. While the three quitter-type subjects still reached level 0.

Algebraic Reasoning Characteristics of Climber, Camper, and Quitter Type Students in Solving PISA Model Problems

The characteristics of algebraic reasoning of climber, camper, and quitter-type students in solving PISA model problems differ according to the level of algebraic reasoning achieved by each student. The characteristics of students' algebraic reasoning are as follows.

Algebraic Reasoning Characteristics of Climber-Type Students in Solving PISA Model Problems

The characteristics of climber-type subjects who meet level 1 are that the subject is able to identify patterns, use symbols in solving problems, and make generalizations based on observed patterns. This is in accordance with research that states that climber-type students (Abdiyani et al., 2019) can write down detailed problem-solving strategies using open sentences. So that students with climber type can meet level 1.

At level 2, the characteristic of climber-type subjects is that the subject uses algebraic language to interpret observed patterns, this is apparent when the subject uses arithmetic sequence formulas to solve problems. This is in accordance with research that states that (Rahayu & Alyani, 2020) climber-type students can understand the concept shown by students can bring up a general form in solving problems. So that students with climber type can meet level 2.

Characteristics of Camper Type Student Algebraic Reasoning in Solving PISA Model Problems

At level 1, the subject of type Camper has the characteristic of spawning symbols and using symbols to solve problems. This is by research that states that students type Camper In making problem planning, you can explain problem planning that will be used as a guideline in solving problems by writing problem-solving strategies using open sentences. So that students with type Camper can meet level 1.

Characteristics of Algebraic Reasoning of Quitter-Type Students in Solving PISA Model Problems

The characteristic of quitter-type subjects is that the subject makes errors in solving problems without being able to formally explain or generalize concepts. This is to research which states that (Saniyyah & Vienna, 2020) quitter-type students make problem-solving guesses so students with quitter type are classified as meeting level 0.

Based on the exposure to the data above, information was obtained that in solving the PISA model problem there was a similarity in the level of algebraic reasoning of climber and camper type subjects, while quitter type subjects met a lower level of algebraic reasoning than camper type subjects.

Conclusion

Students with different adversity quotients reach different levels of problem-solving PISA models. Students with climber-type meet level 1 and 2, camper-type students meet level 1, and quitter-type students meet level 0. The characteristics of algebraic reasoning of climber-type students who can meet level 2 are The subject uses symbols in solving problems, as well as using algebraic language to interpret patterns that have been observed. Subjects who can meet level 1 have the characteristics of Subjects who can identify patterns, use symbols in solving problems, and make generalizations based on observed patterns. The characteristics of camper-type subjects are that they bring up symbols and use symbols to solve problems. The characteristic of quitter-type students' algebraic reasoning is that the subject makes errors in solving problems without being able to formally explain or generalize concepts.

Recommendations

Based on the results of the above research, the following suggestions were put forward: a) For teachers, they should choose interesting learning methods and models and routinely provide various practice questions as an effort to improve students' algebraic reasoning level. b) Further researchers can conduct research with the same or almost the same subject characteristics to see the reliability of the research.

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