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Analysis of Students' Mathematical Problem-Solving Ability and Semiotics in Terms of Adersity Quotient (AQ)

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Abstract

This study aims to analyze students' problem-solving abilities and mathematical semiotics based on Adversity Quotient (AQ). This qualitative research uses a descriptive approach. The research subjects were selected using an AQ questionnaire and conducted in Class IX F of SMP Negeri 14 Raja Ampat, involving three students divided into three groups. The first group consisted of one climber-type student, the second group included one camper-type student, and the third group included one quitter-type student. Data collection techniques included an AQ questionnaire, tests, and unstructured interviews. Data analysis techniques involved data reduction, data presentation, and conclusion drawing. The research results indicate that an analysis of students' problem-solving abilities and mathematical semiotics based on adversity quotient shows that students in the climber category have excellent problem-solving abilities, meeting all four problem-solving indicators according to Polya's theory. These students also demonstrate an understanding of semiotics from Peirce's perspective, successfully solving problems using this approach. Students in the camper category show moderate problem-solving abilities, meeting three indicators: understanding, planning, and executing the problem-solving process, but lack in reviewing their answers. Regarding semiotics from Peirce's perspective, camper-category students can create signs, identify objects, and interpret signs but struggle to complete the final solution. In contrast, quitter-type students display low problem-solving abilities, failing to meet the problem-solving indicators according to Polya's theory or the semiotic indicators from Peirce's perspective.

Keywords: Problem-Solving Ability, Semiotics, Adversity Quotient, Polya's Stages, Peirce's Perspective

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INTRODUCTION

Mathematical problem-solving skills are a key element in mathematics learning, as through this ability, students can sharpen their experience and skills in tackling both routine and non-routine mathematical challenges (Albert & Kim, 2013; Iksanti & Sari, 2023; Shida et al., 2023; Wijayanti et al., 2023). Mathematical problem-solving stimulates the development of critical and creative thinking skills, while providing practice in solving non-routine mathematical problems (Monisa et al., 2023; Nurfatanah, Rusmono, 2018;

Rambe & Afri, 2020). Experience in problem-solving also plays an essential role in broadening mathematical understanding, fostering higher-order thinking skills, and enhancing problem-solving abilities within the learning process (Baraké et al., 2015; Jupri & Hidayat, 2022; Rasiman, 2015).

The process of solving mathematical problems with the use of semiotics becomes important and plays a role in demonstrating the significance of signs and meaning in mathematics (Palayukan et al., 2020; Purwasih et al., 2023). Semiotics is a field of study that examines how signs and symbols are produced, understood, and used in various mathematical communication contexts (Riccomini et al., 2015). In mathematical problem-solving, signs and symbols serve as a means to convey information effectively (Fitriyah et al., 2021; Suci Yongki Setyowati, 2023). According to Hundeland et al., mathematical activities involve interpreting signs and transforming signs to develop knowledge (Per Sigurd Hundeland, Martin Carlsen, 2014). According to Peirce's philosophy, semiosis (the meaning of a sign) is a relationship between the representamen (R), the object (O), and the interpretant (I). R is the part of the sign that can be physically or mentally perceived, which refers to something it represents (O). Then, I is the part of the process that interprets the relationship between R and O. Thus, semiosis is the process by which signs are formed, beginning with the spontaneous representation of objects in the human mind, which is then specifically interpreted by the individual as the interpretant.

Semiotics and mathematical problem-solving abilities can be categorized within Adversity Quotient (AQ). Adversity Quotient is an individual's intelligence in regularly facing obstacles or difficulties. According to Stoltz, a student's AQ can be an indicator of how strong a person can remain resilient when facing a problem. Moreover, AQ can serve as an indicator of how a person handles problems, whether they can solve the issues they encounter to emerge as winners or if they give up or stop when facing challenges deemed difficult to handle (Baharullah et al., 2022; Falah et al., 2023; Fitriyah et al., 2023; Siregar, et al., 2024). Stoltz classifies students' AQ into three categories: quitters, campers, and climbers. First, students with a quitter type are those who give up easily, tend to run from problems, avoid challenges, and even stop or surrender when encountering difficulties. Second, campers are those who are willing to face problems but still avoid taking measured risks, ultimately halting their progress prematurely. Third, climbers are individuals who possess the courage to face problems or risks, enabling them to complete tasks in line with their goals.

Mathematical problem-solving and semiotics involve obstacles that require extensive steps and deep semiotic interpretation to resolve mathematical problems. Consequently, not all students can solve problems following these steps and semiotic interpretations, except for those who have resilience in facing challenges.

METHOD

This study uses qualitative research with a descriptive type of research. The aim of this study is to analyze the problem-solving abilities and mathematical semiotics of students in terms of the Adversity Quotient (AQ) of climber, camper, and quitter types. The subjects in this study are ninth-grade students from SMP Negeri 14 Raja Ampat. Data collection techniques in this study include administering an AQ questionnaire to students, written tests, and interviews.

First, the AQ questionnaire is used to determine the AQ type of students as climbers, campers, or quitters. The criteria used to categorize these three AQ types are based on a normal distribution model. Second, a written test is given to three selected students based on the AQ questionnaire results, consisting of one climber, one camper, and one quitter, to measure their mathematical problem-solving abilities using Polya's steps (Supriadi et al., 2021) and the students' mathematical semiotics from Peirce's perspective (Purwasih et al., 2023). The test used in this study is an essay-type question with non-routine problems. Third, unstructured interviews are conducted. These interviews are held after the students complete the test to reinforce the results obtained from the test. After the AQ questionnaire, written tests, and interviews are conducted, the data are analyzed. Data analysis is carried out using the Miles & Huberman model, starting with data reduction, data presentation, and drawing conclusions (Supriadi et al., 2021).

RESULTS AND DISCUSSION

The results of the adversity quotient (AQ) questionnaire analysis distributed to 9th-grade students of SMP Negeri 14 Raja Ampat show that the students are divided into three categories: climber, camper, and quitter, based on their level of resilience in facing challenges. Students with the climber AQ type, who scored within the interval $X \geq 176$, numbered 14 students or about 56% of the 25 participants. These students show high enthusiasm and resilience in overcoming various difficulties they encounter. Next, there are 8 students, or 32% of all participants, who fall into the camper category, with AQ scores in the interval $112 \leq X < 176$. These camper-type students generally manage to stay at a certain level without showing a strong desire to continue developing, feeling content in their comfort zone. Lastly, 3 students, or 12% of the total participants, fall into the quitter category, with AQ scores in the interval $X < 112$. Students in the quitter category have low resilience and tend to give up quickly when facing obstacles. These categories help in understanding the students' resilience levels in a more structured way, as shown in the following Table 1:

Table 1. Distribution of Adversity Quotient (AQ) Scores of Students

Category	Score Interval	Quantity	Percentage (%)
Students with Climber AQ Type	$X \geq 176$	14	56%
Students with Camper AQ Type	$112 \leq X > 176$	8	32%
Students with Quitter AQ Type	$X < 112$	3	12%

Based on the analysis of the adversity quotient questionnaire, one student was selected from each category—climbers, campers, and quitters—to be the subject of further research. Since each category included more than one student, the selection process was carried out through additional assessment based on the results of a mathematics problem-solving test and semiotics. The selected subjects were those who most dominantly demonstrated characteristics that aligned with the adversity quotient category they represented. Thus, this selection aimed to ensure that each research subject truly represented the type of resilience in facing challenges as defined in the climbers, campers, and quitters categories. The final results of the subject selection are shown in Table 2.

Table 2. Research Subject Categories

Code Name	Score	Category	Subject Code
J-12	107	*Quitters*	**G-1**
J-24	168	*Campers*	**G-2**
J-7	199	*Climbers*	**G-3**

The data in Table 2. The selected subjects were then interviewed to delve deeper into their problem-solving abilities in mathematics and semiotics, which they had previously completed. The purpose of this interview process was to gain deeper insights into the strategies, mindset, and various challenges each subject faced while attempting to solve the mathematics problems. This approach is expected to provide a comprehensive understanding of how each subject, from the different adversity quotient (AQ) categories, approaches and overcomes problems. To ensure a more efficient data analysis and dialogue tracking process, each conversation between the interviewer and the research subjects was assigned a specific code. The interviewer was assigned the code "P" as an identifier, while for the research subjects, each AQ category was given a different code: "G-1" for the climber type, "G-2" for the camper type, and "G-3" for the quitter type.

The research data was then analyzed in-depth through tests and interviews, focusing on the indicators of problem-solving abilities structured according to Polya's problem-solving steps. These steps include four main stages: first, understanding the problem, where students are expected to identify and define the problem clearly; second, planning the solution, which is the process of developing a strategy to find the correct solution; third, executing the plan, where students implement the solution they have devised; and finally, reviewing, which involves evaluating the answer to ensure the accuracy and validity of the solution provided. Additionally, students' semiotic analysis was conducted based on Peirce's semiotic perspective, focusing on three key aspects: the creation of signs (representamen), identification of the object (object), and interpretation of the sign (interpretant). This semiotic approach helps explore how students understand and interpret the symbols or signs used in the problem-solving process, providing additional insights into their thinking patterns and conceptual understanding.

A. **Students with Climber AQ Type**

1. Analysis of Problem-Solving Ability using Polya's Steps

In the first stage, the problem-solving ability was analyzed using Polya's Steps. In the understanding the problem stage, the Climber subject (G-1) demonstrated good analytical skills by clearly identifying the sufficient conditions, which involved identifying the information provided in the problem. However, they were not yet fully able to determine the necessary conditions or the things that needed to be further explored. This indicates that G-1 has the ability to filter out relevant information to efficiently assist in solving the problem. Additionally, G-1 was able to restate the core problem in their own words in a systematic and understandable mathematical form, which shows that G-1 had a sufficient understanding of the context of the problem. Therefore, G-1 was not only able to comprehend the data and questions provided but also capable of translating them into a more structured and mathematical form, though there is still a need to improve in determining the necessary conditions. This is shown in Figure 1, where G-1 is working on understanding the problem.

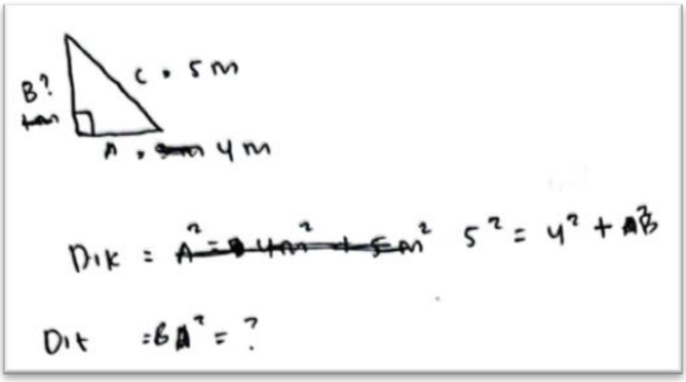

Figure 1. Subject G-1 in the Understanding the Problem Stage

It was emphasized in the interview that G-1 correctly identified the important information in the problem, which included the distance from Dolfina to Yance as the base of the triangle (A), the line of sight from Dolfina to the Cockatoo as the hypotenuse of the triangle (C), and the height from the ground to the Cockatoo's location as the height of the triangle (B). When P asked what was being sought in the problem, G-1 explained that the goal was to find the length of the stick that Yance would need to help the Cockatoo. This response shows that G-1 was able to identify the basic geometric elements in the problem and understood the ultimate goal of the solution, which is to determine the length of the stick as the final result of the necessary analysis and calculations.

In the problem-solving planning stage, the AQ Climber type subject (G-1) demonstrated the ability to use analogy to help find an effective solution strategy. G-1 was able to draw from experiences with similar problems encountered in the past and use their analogical thinking as a reference in determining relevant steps for the current problem. Additionally, the AQ Climber type subject (G-1) accurately selected an appropriate approach or method to solve the problem, showing skill in assessing which strategy was most efficient and aligned with the desired solution. This reflects G-1's ability to adapt and apply flexible and innovative problem-solving strategies.

It was emphasized in the interview that G-1 explained they used the Pythagorean theorem, demonstrating an initial understanding of the relevant mathematical approach. When P asked G-1 to state the complete Pythagorean theorem formula, G-1 correctly stated it as $C^2 = A^2 + B^2$, where C is the hypotenuse of a right triangle, and A and B are the perpendicular sides. This dialogue shows that G-1 understands the basic principle behind the Pythagorean theorem and can recall and express the formula correctly, which is essential for solving geometry problems using an analytical approach.

In the stage of implementing the problem-solving plan, the AQ Climber type subject (G-1) demonstrated strong ability in following the steps according to the chosen approach and strategy. G-1 was able to apply these strategies consistently at each stage of the solution process, showing discipline in adhering to the plan that had been laid out previously. Thus, G-1 not only understood the plan but also effectively implemented it, which highlighted their ability to stay focused and structured in the problem-solving process until the desired solution was achieved. This is shown in image 2, which illustrates G-1's understanding and execution of the problem-solving plan.

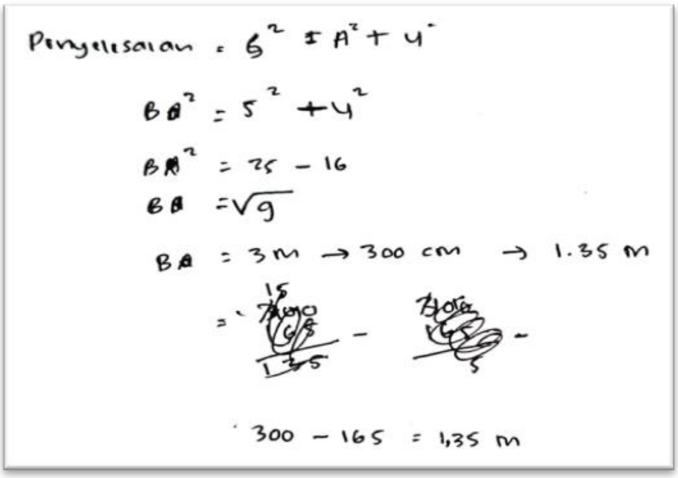

Figure 2. Subject G-1 at the Stage of Implementing the Problem-Solving Plan.

In this conversation, G-1 explained the problem-solving process using the Pythagorean theorem to determine the length of the unknown side of a triangle. G-1 began by writing the basic Pythagorean formula, Pythagoras $C^2 = A^2 + B^2$, and substituted the known values, $A = 4\ m$ and $C = 5\ m$. When asked about the symbols used, G-1 explained that subtraction was done by moving A^2 to the right side, so the equation became $B^2 = 5^2 - 4^2$. G-1 then broke down the calculation, first computing $5^2 = 25$ and $4^2 = 16$, and then subtracting 16 from 25 to obtain $B^2 = 9$. By taking the square root of 9, G-1 determined $B = 3\ m$. After finding that $B = 3\ m$, G-1 proceeded to calculate the length of the stick needed to help Yance assist the Cockatoo. The first step was to convert 3 meters into 300 cm, then subtract the initial height of 165 cm, resulting in a remaining length of 135 cm. Finally, G-1 converted 135 cm into meters, yielding 1,35 meters. This explanation shows that G-1 understands the basic steps involved in solving the problem using the Pythagorean theorem, unit conversions, and performing basic operations to solve a contextual problem.

At the stage of reviewing the answer, the AQ Climber type subject (G-1) demonstrated attention to detail by performing a recalculation to ensure the accuracy of the solution provided. G-1 did not just solve the problem once, but repeated the calculation process to verify that each step and the final result were correct. This step shows G-1's commitment to precision and the quality of their answers, as well as their ability to critically review their work, ensuring that no errors were made in the problem-solving process. This was further emphasized during the interview, where G-1 stated that their method for checking the answer was to revisit the calculations using the formula they had learned. When asked if they were confident in the answer they obtained, G-1 confidently stated that the answer was correct. When further asked about the method used to check the answer, G-1 explained that they used the Pythagorean theorem, $C^2 = A^2 + B^2$, to ensure the accuracy of the result.

2. **Mathematical Semiotic Analysis of Students Based on Peirce's Perspective**

In addition to analyzing mathematical problem-solving abilities, the students' semiotics were also analyzed from Peirce's perspective, which includes sign creation, object identification, and sign interpretation. In Figure 1, it can be seen that the response of subject G-1 has included Peirce's semiotic components, namely the creation of signs. Subject G-1 gathered relevant information and represented this information in the form of a triangular object. Each point on the triangle was connected and labeled as A, B, and C. Subject G-1 assigned meanings to the signs A = 4 m, C = 5 m, and B = ?. Thus, subject G-1 demonstrated a strong ability to understand and translate information from the problem into relevant mathematical signs.

In Figure 1, the student engages in activities that correspond to Peirce's semiotic components, including identifying objects. For instance, subject G-1 writes A as the base of the triangle, which is interpreted from the problem "the distance from Dolfina to Yance." Subject G-1 writes C as the hypotenuse of the triangle, interpreted from the problem "the line of sight from Dolfina to the Cockatoo," and subject G-1 writes B as the height of the triangle, interpreted from the problem "the height from the ground to the roof of the cockatoo's nest," which is related to the Pythagorean concept. In this stage, the student writes down the concept they are thinking of when generating the representamen.

The third semiotic component of Peirce is interpreting signs. In Figure 2, the student manipulates the signs that have already been created to apply the Pythagorean concept in order to first find the height of the triangle (A) and then determine the length of the stick Yance needs to rescue the Cockatoo. The student links the signs with prior knowledge, specifically the Pythagorean concept. The student explains the meaning of a concept in detail to correctly solve the mathematical problem. However, the understanding of the use of the equals sign (=) is still somewhat inaccurate. Based on an interview, subject G-1 interprets the equals sign as a transfer from the left side to the right side.

B. Students with Camper AQ Type

1. Analysis of Problem-Solving Ability using Polya's Steps

At the stage of understanding the problem, the camper-type subject (G-2) demonstrated good analytical skills by clearly identifying the sufficient conditions, which involved recognizing the information given in the problem, and was able to determine the necessary conditions or aspects that needed further investigation. This indicates that G-2 has the ability to sift through relevant information to assist in solving the problem efficiently. However, G-2 was not yet able to articulate the core of the problem in their own words in the form of mathematical sentences. Thus, G-2 was able to understand the data and the question given, but was not yet able to translate it into a more structured and mathematical form. This is shown in Figure 3. Subject G-2 in understanding the problem:

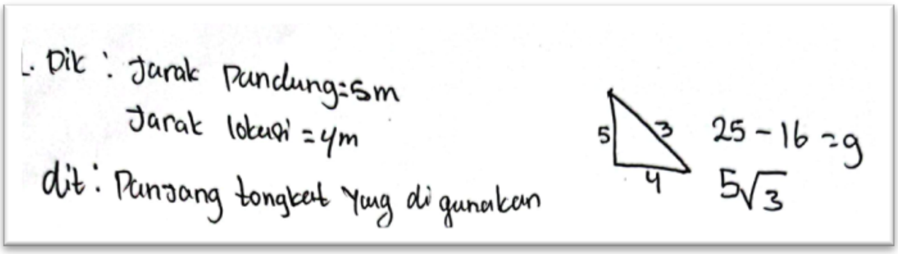

Figure 3. Subject G-2 at the Stage of Understanding the Problem

During the interview, subject G-2 was able to mention the sufficient and necessary conditions in the problem, as emphasized by G-2, who explained that the information they knew in the problem was the distance from Dolfina to the cockatoo, which was 5 meters, and the distance from Dolfina's location to Yance, which was 4 meters. When asked about what was being sought in the problem, G-2 stated that the goal was to find the length of the stick used by Yance to help the cockatoo.

At the stage of making a problem-solving plan, the camper-type subject (G-2) demonstrated the ability to make analogies to help find an effective solution strategy. As emphasized in the interview, subject G-2 explained that they used the Pythagorean theorem to solve the problem. When asked to state the Pythagorean theorem, G-2 mentioned the formula as $S^2 = a^2 + t^2$, which is the basic form of the Pythagorean theorem that states that the square of the length of the hypotenuse of a right triangle is equal to the sum of the squares of the lengths of the other two sides.

At the stage of implementing the problem-solving plan, the camper-type subject (G-2) faced difficulties in completing the mathematical problem until the final stage. Although subject G-2 was able to start the solving process and appeared to understand the initial steps of the solution plan, they encountered obstacles as they approached the final resolution of the problem. This indicates that while subject G-2 has the basic ability to follow the plan that was set, they still require further guidance or additional strategies to achieve a complete solution. In Figure 4 and the interview, it can be seen how subject G-2 attempted to implement the problem-solving plan but was stopped before reaching the final result.

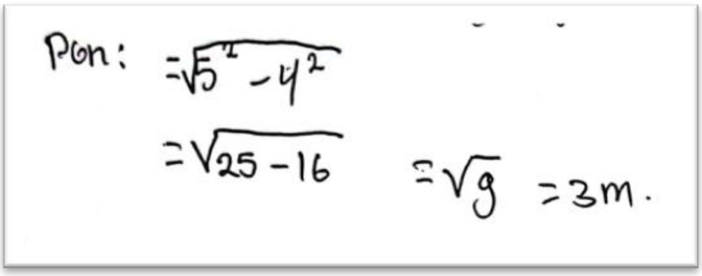

Figure 4. Subject G-2 at the Stage of Implementing the Problem-Solving Plan

As emphasized in the interview, subject G-2 explained the solution process they had written using the Pythagorean theorem. They started by calculating the height of the triangle using the equation $\sqrt{5^2 - 4^2}$. In the first step, they calculated 5×5, which resulted in 25, and 4×4, which resulted in 16. Next, they subtracted 16 from 25, which resulted in 9. From here, they took the square root of 9, which gave 3 meters. When asked if there was anything else to find after obtaining the value of 3 meters, G-2 stated that there was still something to find, which was the length of the stick. However, when asked to explain further, G-2 admitted that they did not know how to find it.

At the stage of reviewing the answer, the camper-type subject (G-2) has not demonstrated the ability to check their answer again. This is due to G-2's lack of understanding of the correct solution steps, which prevents them from verifying the accuracy of the result obtained. This limitation in understanding means that G-2 does not have a strong foundation to perform verification of their answer, indicating the need for guidance in applying effective checking strategies and a deeper understanding of the problem-solving procedure. As revealed in the following interview, G-2 does not yet understand how to review their answer and requires further direction to develop their verification skills.

2. Mathematical Semiotic Analysis of Students Based on Peirce's Perspective

In Figure 3, it can be seen that subject G-2's answer includes Peirce's semiotic components, namely through the process of sign creation. Subject G-2 attempted to gather relevant information and represent it in the form of a triangle. Each side of the triangle was labeled with numbers: the number 4 for one side, the number 3 for the other side, and the number 5 on the third side. These number labels indicate the subject's effort to interpret and associate numeric signs with each side of the triangle, although not yet fully accurately.

In Figure 3, the student engages in an activity from Peirce's semiotic components by identifying objects, including subject G-2's use of the number 4 as the base of the triangle, the number 5 as the height of the triangle, and the number 3 as the hypotenuse of the triangle, which is related to the Pythagorean concept. Although subject G-2 has assigned meaning to these numbers according to their components, there is an error in the placement of the numbers, particularly on the height and hypotenuse sides of the triangle. However, after being confirmed in the interview, subject G-2 admitted that they had incorrectly placed the hypotenuse and the height sides of the triangle.

The third semiotic component of Peirce is interpreting signs. In Figure 4, the student manipulates the signs that have been created to apply the Pythagorean concept to first find the height of the triangle and then determine the length of the stick needed by Yance to help the cockatoo. Subject G-2 relates the signs to prior knowledge, specifically the Pythagorean theorem. Subject G-2 is able to start the solution process and seems to understand the initial steps of the problem-solving plan. However, Subject G-2 faces obstacles as they approach the final resolution of the problem, specifically in determining the length of the stick needed by Yance to help the cockatoo.

C. siswa AQ tipe *quitter*

Subject AQ camper type (G-2), has not yet demonstrated problem-solving abilities according to the indicators developed based on Polya's problem-solving steps, namely understanding the problem, planning the solution, implementing the plan, and evaluating the answer. At each of these steps, the subject faced obstacles that hindered the successful completion of the problem-solving process. Additionally, an analysis of the subject's problem-solving abilities was conducted from the semiotic perspective of Peirce, which involves three main aspects. First, the creation of signs (representamen), which occurs when the subject describes or represents the information in the problem. Second, object identification (object), which is the subject's ability to recognize the key elements of the problem that are relevant. Third, the interpretation of signs (interpretant), which reflects how the subject understands and connects those signs with the knowledge they already possess. The limitations of the subject in executing these three semiotic aspects indicate that G-2 requires a deeper understanding to overcome the obstacles in the problem-solving process.

As emphasized in the interview, subject G-3 revealed that they did not understand the information in the given problem. When P asked about the reason for this lack of understanding, G-3 responded that it was due to the problem being in the form of a word problem, which made it difficult for them. P then asked if word problems were indeed difficult, and G-3 confirmed that they found word problems difficult. When asked about the type of problems they found easier, G-3 explained that they found it easier to understand problems that were not in the form of a story.

The research data above shows that students in the "climbers" category demonstrate excellent problem-solving abilities, as they comprehensively meet all four main indicators based on Polya's theory: 1) understanding the problem; 2) devising a solution plan; 3) executing the solution according to the plan; and 4) reviewing the obtained answer. This aligns with previous studies that found students in the "climbers" category are not only capable of understanding and planning solutions effectively but also excel in implementing solutions and re-evaluating their final results (Baharullah et al., 2022; Supriadi et al., 2021). This evaluative ability provides them with a more critical and reflective approach, which plays an important role in ensuring the accuracy and relevance of the solutions they produce. Additionally, in terms of semiotic analysis based on Peirce's perspective, students in the climber category can solve problems by creating signs, identifying objects, and interpreting signs. This is consistent with previous studies, which found that high-achieving students are able to solve mathematical semiotics based on Peirce's perspective (Purwasih et al., 2023).

On the other hand, research data for students in the "campers" category indicate a moderate level of problem-solving ability, meeting three out of four indicators: understanding the problem, planning, and execution, but encountering challenges in the final evaluation stage. In semiotic analysis according to Peirce, they are also able to create signs and identify objects but face obstacles in interpreting signs as they approach the solution. This aligns with previous research showing that while "campers" can complete most problem-solving steps, their final results are often suboptimal due to insufficient evaluation of the generated solution (Rahmi et al., 2021).

In contrast to the previous two categories, students in the "quitters" category demonstrate low problem-solving abilities, as they fail to meet the indicators of Polya's problem-solving approach or Peirce's semiotic analysis. This deficiency in both approaches suggests that "quitters" face significant challenges in identifying and applying effective solution steps, resulting in inadequate outcomes in mathematical problem-solving. Consistent with previous research on students in the "quitters" category, it was found that this type of student tends to struggle when facing challenges, making them more likely to give up before fully solving the problem (Khasanah, 2021; Supriadi et al., 2021).

CONCLUSION

Based on the research results supported by several theories and previous studies, the analysis of students' problem-solving abilities and mathematical semiotics from the perspective of adversity quotient concludes that students in the climber category have excellent problem-solving abilities by meeting all four indicators: understanding, planning, implementing the problem-solving process, and performing evaluation. Additionally, from the semiotic perspective of Peirce, climber students can solve problems by creating signs, identifying objects, and interpreting signs. Furthermore, camper students were found to have adequate problem-solving abilities, meeting three indicators: understanding, planning, and implementing the problem-solving process. In terms of semiotics based on Peirce's perspective, camper students can solve problems by creating signs, identifying objects, and interpreting signs but face obstacles when approaching the final solution. Meanwhile, students in the quitter category were found to have low problem-solving abilities, not meeting the problem-solving indicators based on Polya's theory and the semiotics of students from Peirce's perspective.

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