ANALYSIS OF MATHEMATICAL CRITICAL THINKING SKILLS THROUGH A SEMIOTIC APPROACH

Zakiyah Anwar[1*], Supriadi[2], Amrin Hamid[3], Hasnawati Mahmuri[4] Ahyani Mirah Liani[5] Nurmala R[6],

[1,2] *Universitas Muhammadiyah Sorong*
[3] *Balai Diklat keagamaan Makassar*
[4] *MAN 2 Kota Makassar*
[5] *Universitas Negeri Makassar*
[6] *Universitas Borneo Tarakan*

[*] *Corresponding author. Email: zakiyahanwar@um-sorong.ac.id*

ABSTRACT
This study aims to analyze critical thinking skills in mathematics through a semiotic approach. Critical thinking abilities function on 4 indicators, namely: (1) interpretation, (2) analysis, (3) evaluation, and (4) inference. This type of research is descriptive research with qualitative approaches. The semiotics approach is divided into 3 components, namely: (1) signs, (2) words, and (3) symbols. The subject selection techniques were based on a purposive sampling technique, with a subject of 27 students of class XI IPA 4 SMA YPPK Agustinus, Sorong City, even semester of the 2022/2023 academic year. The data analysis techniques used are descriptive and qualitative. The instruments used are test instruments and interview instruments. The results showed that the average ability to think critically in mathematics through semiotic approaches was 44.4% (low). Analysis of critical thinking skills in categories namely: 1) high category 1 students (3.70%), 2) medium category 4 students (14.8%), 3) low category 12 students (44.4%), 4) low categories very low 10 students (37%). So it can be concluded that students ' critical thinking skills are still low in class XI IPA 4 SMA YPPK Agustinus, Sorong City

Keywords: *Semiotics; Mathematical Critical Thinking: Thinking Skill*

1. INTRODUCTION

Mathematics is a science that studies abstract things and logical proof. Mathematics is one of the important subjects for students because mathematics functions to develop the ability to communicate using symbols and can help solve problems they face in everyday life [1]. Mathematics learning is a process of interaction between teachers and students that involves developing thinking patterns and processing logic in a learning environment that is deliberately created by the teacher using various methods so that the mathematics learning program grows and develops optimally, and students can carry out learning activities effectively and efficiently.[2]. Critical thinking ability is an important ability for students to have. According to [3], critical thinking is an important aspect of the learning process. This critical thinking ability is important because it can train the ability to think logically, systematically, critically, creatively, and carefully as well as thinking objectively, being open to facing everyday life problems [4]. The ability to think critically in mathematics is the ability to use the mind to search for meaning and understanding and make judgments and decisions in solving mathematical problems [5]. In studying and doing mathematics, everything related to the use of signs/symbols is called semiotics. Semiotics can serve as a theoretical lens through which to investigate a wide variety of topics in mathematics education research. Semiotics in general is a scientific study of studying signs [6]. Semiotics means a sign in the form of a code, symbol, word, icon, object, or gesture. These signs can be captured by the five human senses have implied meanings and play an important role in communication [7], [8] states that the meaning that emerges from a sign is carried out when communicating. Therefore, semiotics is the most important part of communication, especially in mathematics.

N. Djam'an et al. (eds.), *Proceedings of the 5th International Conference on Statistics, Mathematics, Teaching, and Research 2023 (ICSMTR 2023)*, Advances in Computer Science Research 109,
https://doi.org/10.2991/978-94-6463-332-0_8

In general, the semiotic approach will influence students' thinking abilities in solving problems, and semiotics help us understand the role of mathematics as a tool for problem-solving. Apart from that, semiotics also helps in understanding visual representations and forming meaning [9]. So semiotics can be said to be a science or analytical method for studying signs. Students' critical thinking abilities vary, so indicators are needed to determine students' critical thinking abilities. Many experts formulate indicators of students' critical thinking. One of them is to obey [10], [11] which suggests there are four indicators of critical thinking, namely, a. Interpretation, namely the ability to understand and express meaning, b. Analysis, namely identifying the relationship between the information and problems provided with the required concepts, c. Evaluation, namely assessing the credibility and logical strength of the statement, d. Inference is making logical conclusions. Critical thinking ability is a skill needed to solve problems. Apart from that, critical thinking skills are also important to help students practice skills, raise innovative questions to design appropriate solutions, actively build arguments by showing accurate and logical evidence, and minimize the occurrence of errors in solving problems. [11], [12]. The process and results of mathematical critical thinking skills through a semiotic approach are appropriate for analyzing how signs/symbols are used in linear programs. One of them is solving mathematical problems, students are required to be able to use critical thinking skills to solve the problem [13], [14].Based on this explanation, critical thinking skills are skills that use the mind to search for meaning and understanding to make judgments [15], [16], as well as decisions in solving mathematical problems that students have, so that they can be used as guidelines for trying to maximize students' abilities.

2.METHOD

The type of research used in this research is qualitative research with a descriptive approach. This research aims to analyze critical thinking skills in mathematics through a semiotic approach. This research was conducted at YPPK Agustinus High School, Sorong City. The subjects of this research were students in class XI IPA 4 of SMA YPPK Agustinus, Sorong City using purposive sampling. The samples in this research were class XI IPA 4 students consisting of 27 students. This research uses a test instrument consisting of 3 questions on critical thinking skills in mathematics using a semiotic approach with linear programming material. Apart from that, we also used a structured interview instrument. The following are guidelines for assessing critical thinking skills in mathematics:

Table 1. Mathematical Critical Thinking Ability Assessment Rubric

Indicator	Information	Score
Interpretation	Don't write what is known and don't write what is asked	0
	Write down what is known or what is asked incorrectly	1
	Write only what you know accurately or what you ask correctly	2
	Write down what is known and/or asked about the question accurately but incompletely	3
	Write what is known and ask the question correctly and completely	4
Analysis	Do not create mathematical models or strategies that will be used to solve the problems given	0
	Create a mathematical model or strategy that will be used but is inaccurate and incomplete	1
	Create a mathematical model or strategy that will be used to solve the given problem correctly, incompletely, and systematically	2
	Create a mathematical model or strategy that will be used to solve the problem given correctly and systematically, but it is not complete	3
	Create a mathematical model or strategy that will be used to solve the problem given correctly, completely, and systematically	4
	Does not use strategy in solving problems	0

Evaluation	Using inappropriate and incomplete strategies in solving problems	1
	Using the right strategy in solving the problem, but not completely, or using an incorrect but complete strategy in solving the problem	2
	Uses the right strategy in solving problems, is complete but makes mistakes in calculations or explanations	3
	Use the right strategy in solving problems, complete and correct in carrying out calculations or explanations	4
Inference	Make no conclusions	0
	Making conclusions that are incorrect and not appropriate to the context of the question.	1
	Making inappropriate conclusions even though they are adjusted to the context of the question	2
	Make conclusions appropriately, according to the context but not complete	3
	Make conclusions correctly, according to the context of the question, and completely	4

Analyzing mathematical critical thinking ability test data with data extracted using Microsoft Excel to determine parameter estimation results. Apart from that, there are stages to get the estimated results of the indicators used, namely;

1. Classification of Students' Critical Thinking Ability Level in Mathematics.

Table 2. Classification of Students' Critical Thinking Ability Levels

Classification of Critical Thinking Abilities	Information
$0 \leq N \leq 24{,}95$	Very low
$24.95 < N \leq 41{,}56$	Low
$41{,}56 < N \leq 58{,}35$	Currently
$58{,}35 < N \leq 75{,}5$	Tall
$75{,}5 < N \leq 100$	Very high

Source: (Sari, Hidayat, and Harfian, 2018)

Information:

N = Student Value

2. Analysis of Students' Level of Critical Thinking Ability in Mathematics.

$$P_i = \frac{Ai}{N} \times 100\% \quad (1)$$

Information:

P_i= Presentation of indicators of critical thinking abilities

A_i= Many students meet the i-th critical thinking ability indicator

i = Criterion ability level is very good, good, fair, poor, and very poor

N = Number of students who took the test

3. RESULTS AND DISCUSSION

1. Mathematics Critical Thinking Ability Test Results

The average achievement of critical thinking skills in mathematics for 27 students in class XI IPA 4 of SMA YPPK Agustinus, Sorong City is 39.5. So it can be concluded that the average result of the mathematical problem-solving ability of class XI IPA 4 students is 46.25. The results of the critical thinking skills of 27 class XI IPA 4 students based on category level can be seen in the following table;

Table 3. Recapitulation of Mathematical Critical Thinking Ability Categories

KBKM intervals	Number of Students	Percentage	Category
$0 \leq Pi \leq 24{,}95$	10	37%	Very low
$24{,}95 < Pi \leq 41{,}56$	12	44.4%	Low
$41{,}56 < Pi \leq 58{,}35$	4	14.8%	Currently
$58{,}35 < Pi \leq 75{,}5$	1	3.70%	Tall
$75{,}5 < Pi \leq 100$	0	0%	Very high

Table 3 shows that the results of critical thinking ability scores in mathematics in solving problems using a semiotic approach for students in class 12 students were in the low category and 37% of the 27 students were 10 students in the very low category. This shows that the overall level of mastery of the linear program using the semiotic approach of students in class XI IPA 4 SMA YPPK Agustinus is in the low and very low criteria. In the high and medium criteria, students' achievements are very small, so there is a need to improve critical mathematical thinking skills in solving problems using a semiotic approach at YPPK Agustinus High School, Sorong City. The following are the percentage results of indicators of critical thinking ability in mathematics

Table 4. Percentage of Critical Thinking Ability Indicators in Mathematics

Category	Interpretation	Analysis	Evaluation	Inference
Very low	10.49%	7.41%	4.63%	0.93%
Low	23.46%	13.9%	11.1%	9.88%
Currently	10.49%	6.17%	6.48%	7.72%
Tall	3.7%	2.16%	1.85%	1.85%

Table 4 shows that the high category experienced a decrease in interpretation indicators by 3.7%, analysis by 2.16%, evaluation by 1.85%, and inference by 1.85%. Meanwhile, the final score obtained by students in completing the three critical thinking skills questions in mathematics using a semiotic approach for each indicator can be seen in the table as follows:

Table 5. Recapitulation of Scores for Each Question Number 1 Based on the Number of Students

Indicators of Mathematical Critical Thinking Ability	Level of Critical Thinking Ability									
	Very low		Low		Currently		Tall		Very high	
	N	%	N	%	N	%	N	%	N	%
Interpretation	7	4.94%	11	11.1%	4	4.32%	1	1.23%	0	0%
Analysis	6	4.01%	11	6.79%	4	2.16%	1	0.62%	0	0%
Evaluation	8	3.4%	11	7.41%	4	3.09%	1	0.93%	0	0%
Inference	0	0%	7	6.17%	3	3.7%	1	1.23%	0	0%

In each question number 1, there is an indicator for interpreting students who can be in the low category of 11.1% with a total of 11 students, an analysis indicator for students who can be in the low category of 6.79% with a total of 11 students, an evaluation indicator students can be in the low category of 7.41% with a total of 11 students, and in the inference indicator students can be in the low category of 6.17% with a total of 7 students.

Table 6. Recapitulation of Scores for Each Question Number 2 Based on the Number of Students

Indicators of Mathematical Critical Thinking Ability	Level of Critical Thinking Ability									
	Very low		Low		Currently		Tall		Very high	
	N	%	N	%	N	%	N	%	N	%
Interpretation	8	5.25%	11	9.88%	4	4.32%	1	1.23%	0	0%
Analysis	4	3.4%	10	6.48%	4	2.78%	1	0.62%	0	0%

Evaluation	4	1.54%	8	4.01%	4	3.4%	1	0.93%	0	0%
Inference	2	0.93%	7	4.01%	4	4.01%	1	0.31%	0	0%

In each question number 2, there is an interpretation indicator of students having ability in the low category of 9.88% with a total of 11 students, an analysis indicator of students having ability in the low category of 6.48% with a total of 10 students, an evaluation indicator The ability of students is in the low category at 4.01% with a total of 8 students, while in the inference indicator students are in the medium category with 4 students and low 7 students at 4.01%.

Table 7. Recapitulation of Scores for Each Question Number 3 Based on the Number of Students

Indicators of Mathematical Critical Thinking Ability	Level of Critical Thinking Ability									
	Very low		Low		Currently		Tall		Very high	
	N	%	N	%	N	%	N	%	N	%
Interpretation	1	0.31%	3	2.16%	2	1.85%	1	1.23%	0	0%
Analysis	0	0%	1	0.62%	2	1.23%	1	0.93%	0	0%
Evaluation	0	0%	0	0%	0	0%	0	0%	0	0%
Inference	0	0%	0	0%	0	0%	1	0.31%	0	0%

In each question number 3, there is an indicator for interpreting students who can be in the low category of 2.16% with a total of 3 students, the analysis indicator for students who can be in the medium category of 1.23% with a total of 2 students, in the indicator The evaluation of students having abilities is in the very low, low, medium, high, very high categories of 0%, while the inference indicator of students having abilities is in the high category of 0.31% with a total of 1 student. This shows that the students are less capable of solving essay questions, but their ability to use symbols or signs or use a semiotic approach to interpret is good. However, at the next stage, students experienced a decline. Students still need more teacher guidance to achieve these abilities. The recapitulation of scores to determine the criteria for classifying critical thinking skills in mathematics in solving problems using a semiotic approach for students in class XI IPA 4 SMA YPPK Agustinus based on indicators is as follows:

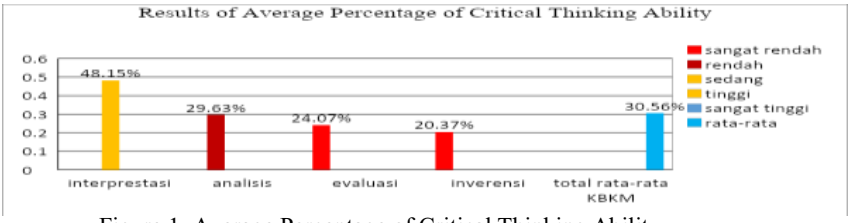

Figure 1. Average Percentage of Critical Thinking Ability

Based on the diagram above, shows that the average value of critical thinking ability in mathematics for class XI IPA 4 SMA YPPK Agustinus in solving problems using a semiotic approach is 30.56% in the low category. The interpretation indicator is 48.15%, the percentage is in the medium category, the analyzing indicator has a percentage of 29.63%, percentage is in a low category, the student evaluation indicator has a percentage of 24.07%, in the very low category, and the inference indicator has a percentage of 20.37%, which means that the percentage is in the very low category so it can be concluded that students' critical thinking abilities in mathematics are in the medium category, namely they are only capable of interpreting indicators.

2. Determination of Research Subjects

When selecting research subjects, researchers utilized data obtained from the results of critical thinking ability tests in mathematics. This data was obtained based on indigo calculations. On Thursday, January 19, 2023, in the 1st and 2nd hours, the researcher gave a critical thinking ability test in mathematics in class 4 students who have medium ability, 12 students who have low ability, and 10 students who have very low ability. Next, 1 student each was selected to be the research subject for the interview instrument on Friday, January 20, 2023. The following are the names of the subjects with their ability categories.

Table 8. Initial list of students' mathematical critical thinking abilities

No.	Subject Name Initials	Mark	Category
1.	GA	64.59	Tall
2.	H	52.08	Currently
3.	A.E	37.5	Low
4.	IL	4.16	Very low

Discussion

This research data is data from the results of a mathematical critical thinking ability test. Description of data from the results of interviews with research subjects I to research subjects IV in completing the mathematical critical thinking ability test on linear program material for which scoring has been carried out, based on the guidelines for scoring critical thinking abilities in mathematics. The following is an analysis of critical thinking skills in mathematics through a semiotic approach:

1. Students with High Critical Thinking Ability

   In this study, it was found that only 1 student had high critical thinking skills in mathematics, namely the GA subject. The following are the results of researchers' interviews with GA subjects on evaluation indicators and inference indicators:

   Researcher: *How many solutions do you know*?

   GA Subject: *There is one solution*

   Researcher: *One? Certain*?

   Subject GA: *No Sis, there are several, namely, there are similarities, continue to find coordinate points, elimination, substitution, and the objective function*.

   Researcher: *How do you determine the conclusion from this question*?

   GA Subject: *How I determine conclusions from the results obtained and asked about the question.*

   GA subject is included in the indicators of interpretation, analysis, evaluation, and inference which are seen in 3 semiotic approaches, namely gesture, word, and symbol. In the gesture approach, GA subjects were able to detail and write down all the information known and asked about, which was needed to solve the problem. In the word approach, GA subjects can translate, draw, and create mathematical models from explanations of the concepts and mathematical models used. In the symbol approach, GA subjects create symbols by observing existing patterns and paying attention to similarities or differences.

2. Students with Medium Critical Thinking Ability

   In this study, there were only 4 students who had moderate critical thinking skills in mathematics, namely subject H, subject CMP, subject RLH, and subject CW. In the interpretation indicator, subject H's ability is very low. The following are the results of the researcher's interview with subject H on interpretation indicators and analysis indicators.

   Researcher: What is known and what is asked?

   Subject H: *The first thing that is known is the capacity of the plane, the capacity of the plane is 50 seats, after that the plane is also divided into two classes, namely economy class and first class. In economy class, there are 20 kilos of baggage for each person taking*

economy class, while in first class there are 50 kilos of baggage carried. where the price for economy class is Rp. 350,000 and for first class it is Rp. 750,000
Researcher: *Do you easily understand the meaning of the question*?
Subject H: *Yes. This question asks what the maximum number of tickets is*.
Researcher: *Try to explain the meaning of the question*!
Subject H: *This question asks how many seats in first class should be for ticket sales to generate maximum income*.
Researcher: *Is there enough information on the question*?
Subject H: *More than enough.*
Researcher: *How do you create a mathematical model*?
Subject H: *Judging from what is known, usually from me, I look at things that are more specific, for example, looking at the questions, it is known that the economic class is known and mainly this can be seen from the questions*.
Researcher: *What formula did you use to solve the problem*?
Subject H: *I use a linear program to solve a problem in the linear program it starts with us looking for previously known equation points, after that we look for points so we can draw the graph and we can look for corner points which will be used with the objective function to can find out the maximum value*.
Researcher: *Why did you choose this formula to solve the problem*?
Subject H: *Because I think using this formula is much easier to solve*.
Subject H is found in the indicators of interpretation, analysis, evaluation, and inference which are seen in 3 semiotic approaches, namely gesture, word, and symbol. Meanwhile, with the evaluation indicators and inference indicators in the semiotic approach, namely gestures, words, and symbols, subject H can detail and write information, translate, and draw from explanations of mathematical model concepts, and create symbols by observing existing patterns.

3. Students' Low Critical Thinking Ability.
The answer sheet for subject AE can be seen in Figure 4 as follows. The following are the results of the researcher's interview with subject A on evaluation indicators and inference indicators: Researcher: *How many solutions do you know*?
Subject AE: *What I know is that you can use a direct method that uses a mathematical model, then create an objective function, and so on. But after I studied more, it turned out that there was a simple way to use direct substitution elimination*
Researcher: *Why didn't you fill in the next section*?
Subject AE: *Because I forgot the last formula, then the time ran out and that's it*
Researcher: *Are you sure that all these answers are correct*?
Subject AE: *Because it's not finished yet, so I'm not sure*
Subject A is found in the indicators of interpretation, analysis, evaluation, and inference which are seen in 3 semiotic approaches, namely gesture, word, and symbol. In the indicators of interpretation and analysis through a semiotic approach, namely gestures, words, and symbols, subject A can detail and write information, translate, and draw from explanations of mathematical model concepts, and create symbols through observing existing patterns. Meanwhile, the evaluation indicators and inference indicators from the interview results of subject A are because or for the reason that time has finished so they cannot write answers.

4. Critical Image Thinking Ability is Very Low
In this study, there were 10 students in the very low critical thinking ability category. One of the subjects with a very low critical thinking ability category is the IL subject.
Researcher: *Why didn't you fill in the next section*?

Subject IL: *Because I forgot the linear programming material, I couldn't do it all*

Subject IL was only able to write the known information on 2 question numbers out of 3 questions and 1 number was not worked on, so it only fulfilled 1 interpretation indicator even though it was incomplete. However, other indicators are not yet possible. In the IL subject analysis indicators, they have not been able to translate or create mathematical models from explanations of the concepts and mathematical models used appropriately and correctly. This causes subject I to be unable to complete the next stage.

Based on the description above, it can be concluded that students who are in the very low critical thinking ability category are only capable of interpreting indicators, namely selecting information that is used (known), but the information written down is not complete. Therefore, it can be concluded that students who have poor critical thinking skills in mathematics are only able to fulfill the interpretation and analysis indicators, but the campus lacks the evaluation and inference indicators. The results of this research are supported by previous research, it was found that students with low critical thinking skills were only able to understand the questions well, but when analyzing, making mathematical models, the strategies used and looking for relationships, and calculating students made mistakes in calculating so that the conclusion what you get is also not true.

4. CONCLUSION

Based on the research results after analyzing the level of critical thinking skills in mathematics in solving problems, it is known that students' critical thinking skills in mathematics meet the low criteria. It can be seen from the results of the analysis of the mathematical critical thinking ability test of students in class (14.8%) had moderate ability, there were 12 students (44.4%) who had low ability, and there were 10 students (37%) who had very low ability. Overall, it was found that the critical thinking skills in mathematics of students in class which can be seen from the semiotic approach, namely gestures and words, while students' analytical skills are still lacking which results in students being unable, but seen from the semiotic approach, namely gestures, words and symbols. Participants can show what should be used in solving questions in the next skills, namely evaluation and inference. In each question number 1, there is an interpretation indicator for students in class students have abilities in the low category of 7.41%, and in the inference indicator students have abilities in the low category of 6.17%. In each question number 2, there is an interpretation indicator for students in class Students' abilities are in the low category at 4.01%, while in the inference indicator students are in the medium and low categories at 4.01%. In each question number 3, there is an indicator for the interpretation of students in class Students' abilities are in the very low, low, medium, high, and very high categories at 0%, while the intervention indicator for students' abilities is in the high category at 0.31%. students in class However, at the next stage, students experienced a decline. Students still need more teacher guidance to achieve these abilities. Therefore, efforts are needed to improve critical thinking skills in mathematics in solving essay questions through a semiotic approach in linear programming by teachers using learning methods and models that can help improve critical thinking skills as well as providing practice questions that support improving students' critical thinking skills in mathematics.

5. REFERENCES

[1] T. D. Lestari, M. Muhyani, H. M. H.Mukhtar, and S. Asmahasanah, ‘Pengaruh Pendekatan Matematika Realistik Terhadap Prestasi dan Karakter Jujur Kelas III SDIT Al-Madinah Cibinong Bogor’, *Jurnal Gentala Pendidikan Dasar*, vol. 4, no. 2, pp. 151–165, Aug. 2019, doi: 10.22437/gentala.v4i2.7150.

[2] E. Susanto and H. Retnawati, 'Perangkat pembelajaran matematika bercirikan PBL untuk mengembangkan HOTS siswa SMA', *Jurnal Riset Pendidikan Matematika*, vol. 3, no. 2, p. 189, 2016, doi: 10.21831/jrpm.v3i2.10631.

[3] R. Rahaju, 'Students' critical thinking skills in making mathematical problems', *Journal of Physics: Conference Series*, vol. 1318, no. 1. 2019. doi: 10.1088/1742-6596/1318/1/012094.

[4] T. P. Naomi, D. Anzelina, N. Sembiring, R. Sinaga, and E. J. Simarmata, 'Penerapan Model Pembelajaran Project Based Learning Untuk Meningkatkan Kemampuan Berfikir Kreatif Siswa Pada Tema 7 Peristiwa Dalam Kehidupan', *Journal on Education*, vol. 6, no. 1, pp. 3229–3240, Aug. 2023, doi: 10.31004/joe.v6i1.3373.

[5] S. J. Kurniawan and F. A. Rahman, 'Implementation of Deep Dialogue/Critical Thinking in Guidance and Counseling Services: Critical Role Solutions Improve Thingking Skills on Z Generation', *Social, Humanities, and Educational Studies (SHEs): Conference Series*, vol. 2, no. 2, pp. 47–55, Aug. 2019, doi: 10.20961/shes.v2i2.38545.

[6] E. W. Kuiler, 'Knowledge formulation in the health domain: A semiotics-powered approach to data analytics and democratization', *Data Democracy: At the Nexus of Artificial Intelligence, Software Development, and Knowledge Engineering*. pp. 127–146, 2020. doi: 10.1016/B978-0-12-818366-3.00007-1.

[7] P. M. de Souza, 'Towards a semiotic-based approach to the design of therapeutic digital games', *IFIP Advances in Information and Communication Technology*, vol. 527. pp. 53–62, 2018. doi: 10.1007/978-3-319-94541-5_6.

[8] C. Suryaningrum, 'Multiple representations in semiotic reasoning', *Journal of Physics: Conference Series*, vol. 1315, no. 1. 2019. doi: 10.1088/1742-6596/1315/1/012064.

[9] I. M. Fitriyah, Y. Arrifadah, and S. Lailiyah, 'Semiotics of mathematics problem-solving in Mason ' s generalization', vol. 8, no. 1, pp. 1–21, 2021.

[10] P. D. Anggraini and D. A. Pramudita, 'Peningkatan Kemampuan Belajar Matematika melalui Penerapan Pendekatan Problem Solving', *Buletin Pengembangan Perangkat Pembelajaran*, vol. 3, no. 1, Aug. 2021, doi: 10.23917/bppp.v3i1.19386.

[11] M. B. Prasetiyo and B. Rosy, 'Model Pembelajaran Inkuiri Sebagai Strategi Mengembangkan Kemampuan Berpikir Kritis Siswa', *Jurnal Pendidikan Administrasi Perkantoran (JPAP)*, vol. 9, no. 1, pp. 109–120, Aug. 2020, doi: 10.26740/jpap.v9n1.p109-120.

[12] M. Setyawan and H. D. Koeswanti, 'Pembelajaran Problem based learning Terhadap Berpikir Kritis Peserta Didik Sekolah Dasar', *MIMBAR PGSD Undiksha*, vol. 9, no. 3, pp. 489–496, Aug. 2021, doi: 10.23887/jjpgsd.v9i3.41099.

[13] Z. Anwar, Sundari, Hidayani, and M. Awal, 'Peningkatan Aktivitas Siswa dengan Penerapan Pendekatan Open-Ended Berbasis PAIKEM', *GAUSS: Jurnal Pendidikan Matematika*, vol. 3, no. 1, pp. 74–85, Aug. 2020, doi: 10.30656/gauss.v3i1.2170.

[14] Z. A. B, A. Maryam, and R. E. Ahmad, *Proceedings of the 7th Progressive and Fun Education International Conference (PROFUNEDU 2022)*, vol. 1, no. November 2019. Atlantis Press SARL, 2022. doi: 10.2991/978-2-494069-71-8.

[15] Z. Anwar and R. Ruslan, 'Pengembangan Perangkat Pembelajaran Matematika dengan Menggunakan Model Pembelajaran Berbasis Masalah', *Qalam : Jurnal Ilmu Kependidikan*, vol. 8, no. 2, p. 92, 2019, doi: 10.33506/jq.v8i2.770.

[16] Z. Anwar and R. Bin Arsyad, 'Profil Kemampuan Siswa SMP dalam Memecahkan Masalah Matematika Open-Ended Berdasarkan Kemampuan Prasyarat Tinggi', *Qalam : Jurnal Ilmu Kependidikan*, vol. 7, no. 2, p. 107, 2019, doi: 10.33506/jq.v7i2.369.