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Analysis of Epistemological Obstacles Experienced by Indonesian Junior High School Students in Solving Mathematical Literacy Problems viewed from Algebraic Thinking Skills

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Abstract: Analysis of Epistemological Obstacles Experienced by Indonesian Junior High School Students in Solving Mathematical Literacy Problems viewed from Algebraic Thinking Skills. The low level of mathematical literacy skills can happen due to learning obstacles. There are various learning obstacles, one of which arises from students' errors or limitations in understanding a particular concept and context of the material, known as epistemological obstacles. One effort to improve mathematical literacy skills is by optimizing algebraic thinking abilities. This is why algebraic thinking is considered a focus of review. However, many students who transition from concrete to abstract thinking experience obstacles in algebraic thinking, including students in grade VIII. This study aims to analyze the epistemological obstacles junior high school students face in solving mathematical literacy problems from the perspective of their algebraic thinking skills. The research method is descriptive qualitative with research subjects of grade VIII junior high schools in Jaten who were then selected two students from each group of high, medium, and low algebraic thinking. The research data includes algebraic thinking ability tests, mathematical literacy tests, and interviews. The study results show that students with medium and low algebraic thinking abilities experienced epistemological obstacles in solving mathematical literacy problems. In contrast, students with high algebraic thinking abilities did not have experienced epistemological obtacles. This study concluded that there are differences in the characteristics of epistemological obstacles between students in the medium and low algebraic thinking ability groups, as identified by the indicators of epistemological obstacles.

Keywords: epistemological obstacles, mathematical literacy, algebraic thinking

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INTRODUCTION

Mathematics plays an important role in life, being one of the fundamental sciences that significantly impact life, including the development of science and technology (Fauziyah & Jupri, 2020). Mathematics is also a subject that not only teaches calculation skills but also the ability to think logically, critically, creatively, and systematically (Dewi & Maulida, 2023), which is necessary to face the challenges of the 21st century (Pujiastuti et al., 2020). Therefore, students will gain many benefits if they possess strong mathematical skills. There are various aspects of mathematical abilities that students must master, according to the National Council of Teachers of Mathematics NCTM 2000, including

problem-solving skills, mathematical communication, mathematical connections, mathematical reasoning, and representation (Fauziyah & Jupri, 2020). These five competencies can be summarized in mathematical literacy skills (Hasanah & Hakim, 2022). So, mathematical literacy skills are important in optimizing students' mathematical mastery abilities.

Mathematical literacy is formulating, applying, and interpreting various mathematical problems (Kusuma et al., 2022). Mathematical literacy includes mathematical and non-mathematical contests in a problem (Kolar & Hodnik, 2021). Mathematical literacy requires a person to use their ability in reasoning and application of mathematical concepts, techniques, facts, and tools to solve various life problems (Genc & Erbas, 2019; Kusuma et al., 2022). Students with good mathematical literacy skills tend to adjust between mathematical concepts and their problems. The importance of mathematical literacy for students does not match the reality on the ground, which shows that the quality of mathematical literacy for Indonesian students still needs to improve. Based on PISA (The Programme for International Student & Àëàêàòent in 2022 in the category of mathematical literacy, Indonesia is ranked 70 out of 81 countries. So, it is necessary to take action to help students improve their mathematical literacy skills, one of which is by minimizing the existence of learning obstacles experienced by students. The existence of these learning difficulties or obstacles is an indication of the existence of learning obstacles (Sidik et al., 2021). Brousseau groups learning obstacles into three categories, namely ontogenical obstacles (related to students' mental readiness to learn), didactical obstacles (associated with the selection of models, methods, and teaching less appropriate books), epistemological obstacles (related to the limitations of students' knowledge on certain themes or contexts) (Maknun et al., 2022). Epistemological obstacles are obstacles that are most often experienced by students when solving mathematical problems (Dewi et al., 2022), and they occur because students find errors in understanding certain mathematical concepts and contexts. In other words, the student's understanding of the concept holds the main control over the occurrence of epistemological obstacles. This is what underlies this study's focus on epistemological obstacles because they are directly related to students, so it is important for teachers to identify the occurrence of epistemological obstacles.

The close relationship between mathematical literacy skills and life problems is based on the fact that mathematical literacy questions involve real-world problems. This is supported by the statement that problem-based assignments in life are one of the efforts to improve mathematical literacy skills (Susanta et al., 2023), and one of the materials that often intersects with life problems is algebra (Allolayuk et al., 2024). In line with the statement (Rohim et al., 2021), one of the efforts to improve mathematical literacy skills is increasing knowledge of algebraic material. So, there is indeed a close relationship between mathematical literacy skills and algebraic concepts.

Algebraic concepts are presented in an algebraic thinking activity that students need when faced with a problem. The ability to think algebraically is an ability that involves mental processes related to reasoning about something unknown, generalizing and making relationships between quantities, and using variable concepts (Sibgatullin et al., 2022). According to Lew, several algebraic thinking activities include generalizing, abstracting, analytical thinking, dynamic thinking, modeling and organizing (Utami et al., 2020). However, it is still found that many students have difficulty thinking abstractly and have low algebraic thinking abilities (Rahmawati et al., 2019), especially junior high school students who are still at the transition stage from concrete

thinking to abstract thinking(Sibgatullin et al., 2022; Töman & Gökburun, 2022).

Several studies that raise the topic of algebraic thinking skills show that there are indeed differences in characteristics between students with high, medium, and low algebraic thinking skills. Research (Sari et al., 2020) shows that students with high algebraic thinking skills can meet most of the indicators when viewed from the algebraic thinking indicators. Students with medium algebraic thinking skills are able to meet more algebraic thinking indicators than students with low algebraic thinking skills. Furthermore, research (Fauziyah & Masduki, 2023) shows that one of the causes of obstacles to algebraic thinking in students with low algebraic thinking skills is due to limited understanding of algebraic concepts and students will tend to solve problems less efficiently (Chan et al., 2022).

Several previous studies discussing epistemological obstacles show that many epistemological obstacles are still found in learning, particularly in certain mathematical topics(Dewi et al., 2022; Siagian et al., 2022; Maknun et al., 2022.; Sulastri et al., 2022; Sunariah & Mulyana, 2020). These studies identified the presence of epistemological obstacles in the topics of statistics (Dewi et al., 2022), inequalities (Siagian et al., 2022), trigonometry (Maknun et al., 2022), limits and functions (Sulastri et al., 2022), and geometric transformations (Sunariah & Mulyana, 2020). The researchers agree that the epistemological obstacles experienced by students are due to a limited understanding of these concepts, including their prerequisite material. However, in previous research, studies have yet to be found that discuss epistemological obstacles in solving mathematical literacy problems, even though mathematical literacy problems can serve as a tool to help improve mathematical literacy skills.

Based on the presentation of these issues, conducting a more in-depth study on epistemological obstacles in solving mathematical literacy problems, involving algebraic thinking skills due to the connection between mathematical literacy and algebraic thinking is important. This is the rationale for conducting this study, describing the epistemological obstacles of grade VIII junior high school students in solving mathematical literacy problems reviewed from algebraic thinking skills. The statement that epistemological obstacles have been found in certain mathematical topics has been presented in previous research. Subsequently, as a follow-up, further research within a broader scope is conducted to answer how junior high school students experience epistemological obstacles when solving mathematical literacy problems involving algebraic thinking skills. By recognizing how epistemological obstacles occur among students when solving mathematical literacy problems from the perspective of algebraic thinking, teachers can use this knowledge to develop learning strategies that minimize the occurrence of epistemological obstacles, ultimately improving the quality of learning and students' mathematical literacy skills.

METHOD

Participant

The subjects in this study were 27 students from class VIII B, from which six students were selected, with two students from each group of high, medium, and low algebraic thinking abilities. The selection of these subjects was based on the teacher's recommendation, which was to choose subjects who could express their opinions well, thus falling under purposive sampling because the subjects were selected based on the criteria and indicators needed in the research.

Research Design and Procedures

This study was conducted to describe epistemological obstacles in solving mathematical literacy problems and was reviewed from the

perspective of algebraic thinking skills. It is a qualitative study (Stahl & King, 2020) with a case study approach in descriptive research design. The research took place at a Junior High School in Grade VIII in Jaten from April to May 2024.

The research began with an algebraic thinking skills test for all students in class VIII B. The test results were then scored, each item graded based on the scoring guidelines prepared, using a scale of 0 to 4. The scores were then converted into a 0 to 100 interval based on the following assessment guidelines.

$$N = \frac{Total\ correct\ score}{Total\ overall\ score} \times 100$$

Based on these scores, students were grouped according to their algebraic thinking abilities; Table 1. shows the guidelines from the ideas of (Badawi et al., 2016).

Table 1. Criteria for grouping algebraic thinking ability

Category	Value Interval
High	$66.67 < x \leq 100$
Medium	$33.33 < x \leq 66.67$
Low	$0 < x \leq 33.33$

The researcher selected two students from each category of algebraic thinking ability, who then took a mathematical literacy test. Based on the literacy test results, the researcher examined, assessed, and analyzed the students' skills and understanding in completing the test. Afterward, interviews were conducted with these six students to explore more deeply the epistemological obstacles they encountered in solving the mathematical literacy problems.

Instrument

This research utilized several instruments, including test instruments such as the algebraic thinking skills test and the mathematical literacy test, as well as non-test instruments such as interview guidelines. The algebraic thinking skills test instrument consisted of 3 essay questions on the topic of the system of linear equations in two variables, developed by the researcher by adapting the ideas of (Sari et al., 2020) related to the components of algebraic thinking and indicators of algebraic thinking skills. This instrument was used to evaluate how well the students fulfilled the components of algebraic thinking, which include generalization, abstraction, dynamic thinking, modeling, analytical thinking, and organization. The mathematical literacy test instrument consisted of 1 essay question on the topic of the system of linear equations in two variables, developed by the researcher by adapting the ideas of (Purwanti et al., 2021) related to mathematical literacy processes and indicators of mathematical literacy, with the selection of content domains and contexts relevant to the chosen topic, specifically the algebra content domain and the personal context domain.

Problem: Bakery

Mama Bakery" bakery sells various breads that can be chosen as a preparation for Eid. The shop provides special packages for the Ramadan edition, including:

(a) Package A contains two cookies and three muffins for Rp. 110.000
(b) Package B contains five cookies for Rp. 100.000, but the buyer will get a discount of Rp. 50.000
(c) Package C contains four cookies and 1 muffin
(d) Package D contains two muffins and two cookies

Based on the illustration above, determine the price for one muffin and one cookie respectively? Through these instruments, the researcher evaluated whether students were able to perform the processes of mathematical literacy, which include formulating problems, applying

concepts, and interpreting the results of their solutions. These evaluations would later be used as additional material to analyze the occurrence of epistemological obstacles experienced by students.

The interview guidelines consisted of 10 questions designed by the researcher, taking into account the indicators of learning obstacles in mathematical literacy, with each indicator represented by at least one question. These indicators were developed by the researcher by adapting the concept of epistemological obstacles from Brousseau's ideas (Hariyani et al., 2022) and were then adjusted to align with epistemological obstacles in mathematical literacy. The questions in the interview guidelines focused on what students experienced and felt while solving mathematical literacy problems, including their knowledge related to the system of linear equations in two variables.

Data Analysis

The data analysis process was conducted using the Miles and Huberman model, which includes the processes of data reduction, data presentation, and conclusion drawing. In the reduction process, the researcher grouped students based on their algebraic thinking abilities according to the scores they obtained and then selected only two students from each category. The selection of subjects was based on the teacher's consideration, choosing students with good communication skills in expressing their opinions. A mathematical literacy test was then administered, but only to the selected subjects. Based on the literacy test results, the researcher examined and analyzed the students' skills and understanding in completing the literacy test, guided by the types of epistemological obstacles that occurred, including conceptual obstacles, procedural obstacles, and technical operational obstacles, which referred to the ideas of (Dewi et al., 2022). and also took into account the indicators of learning obstacles in mathematical literacy. Subsequently, the researcher analyzed the results of interviews with the students. In the data presentation process, the results of the literacy test and interview analysis were presented in a narrative form. Then, a combined analysis was conducted to see whether the data from the literacy test and interview results supported each other, ensuring the validity of the data used through method triangulation. In the conclusion drawing process, the valid data was used by the researcher to make conclusions by describing the epistemological obstacles that occurred, including conceptual obstacles, procedural obstacles, and technical operational obstacles in solving mathematical literacy problems.

■ RESULT AND DISCUSSION

The following results were obtained based on the results of the algebraic thinking ability test that was conducted on all students, it was shown that there were 10 students with high algebraic thinking ability, 12 students with medium algebraic thinking ability, and 5 students with low algebraic thinking ability**.**

The results of the analysis of epistemological obstacles that occurred in students in solving mathematical literacy problems based on the category of algebraic thinking ability are as follows.

Conceptual, Procedural, Technical and Operational Obstacles of Student with High Algebraic Thinking Skills

Conceptual Obstacles

Figure 1 shows that Ummy already has a pretty good conceptual understanding of the system of linear equations in two variables material, which is used as the basis for solving mathematical literacy problems. This is evidenced by the students' answers, which enabled them to understand the given issues, correctly write down the problem's solution, conclude, and reinterpret

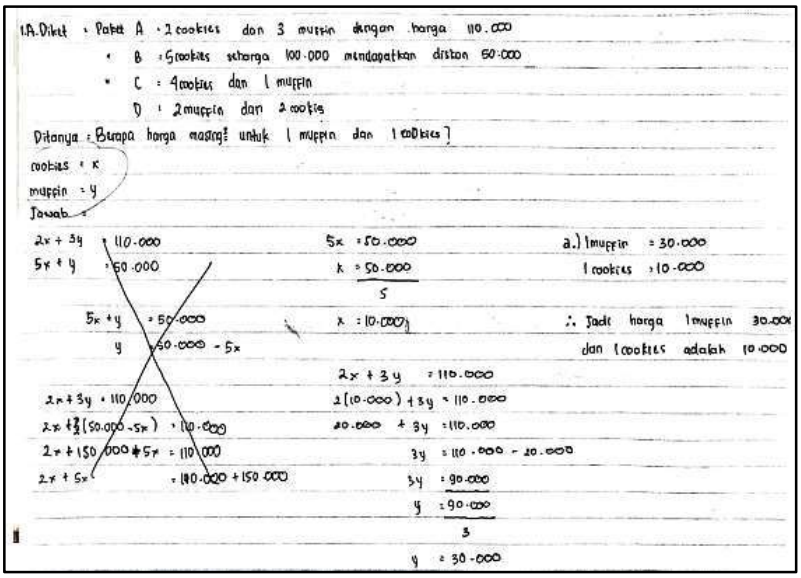

Figure 1. Results of the Al literacy test

them in a natural context. However, there is a slight error in the example of the variables x and y, which should represent the price of cookies and the price of muffins. However, this error does not affect the written solution, which is shown from the conclusions and interpretations written by the subject, which are correct. This indicates that a good conceptual understanding of the system of linear equations in two variables material helps subjects solve mathematical literacy problems well (Isnaniah & Imamuddin, 2020).

Then, based on the interview with subject Al, no conceptual obstacles were found in solving literacy problems. The following is an excerpt from the interview.

Researcher : When you study this system of linear equations in two variables material, do you think this material is difficult or not? And if so, can you explain what difficulties you experienced?

Student: As far as I remember, the material wasn't tricky, ma'am. So I didn't encounter any difficulties.

Researcher: Wow, that's great. Then, what would the score be if I asked you to give a score related to your understanding of this system of linear equations in two variables material from 1-10?

Student : Maybe between 8 or 9 maybe, ma'am

Based on the interview excerpt above shows that A1 has a good understanding of the system of linear equations in two variables material. This is indicated by Al, who did not encounter any difficulties in the material, and the assessment of his own knowledge of the material is in the excellent range. This shows that subject Al has a good conceptual understanding of the system of linear equations in two variables material.

Researcher: Can you give another example of the application of the system of linear equations in two variables material in life?

Student: Perhaps the problem related to monthly grocery shopping at the supermarket, ma'am

Based on the interview excerpt above, it shows that subject A1 has a fairly good understanding of the system of linear equations in two variables material, including its application

in real-life problems. This is demonstrated by the subject's ability to provide another example of applying the system of linear equations in two variables material, even though the example given is not much different from the problem that has already been solved.

Based on the conceptual obstacles indicators and the analysis description above, subject A1 does not experience limitations in understanding the system of linear equations in two variables material and has a pretty good understanding of the material, including the application of system of linear equations in two variables material in life. So, no conceptual obstacles were found in subject Al.

Prosedural Obstacles

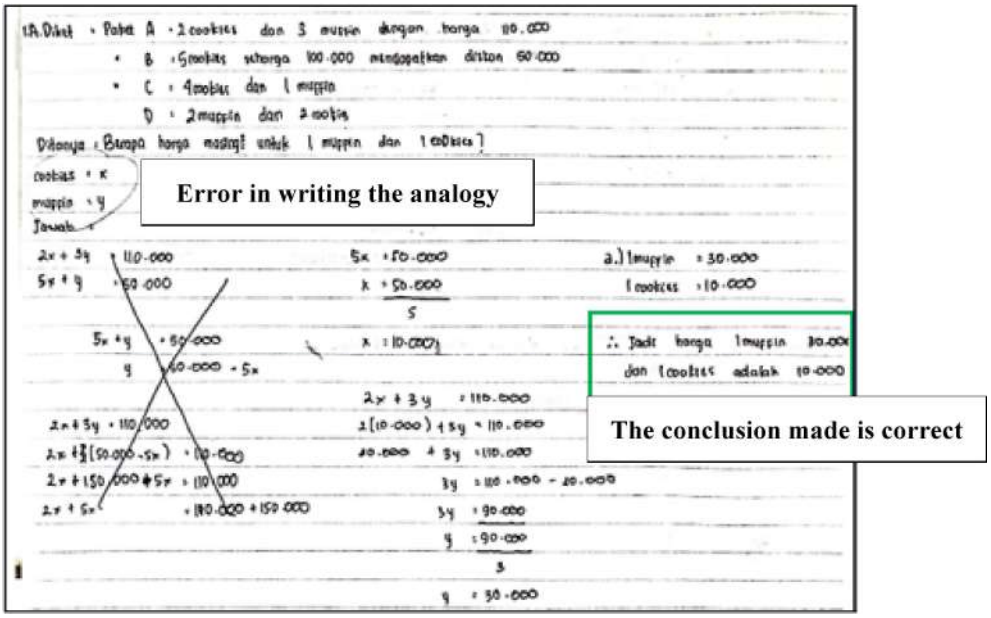

Figure 2. Results of the Al literacy test

Figure 2 shows that overall, subject Al is able to write the steps of the solution correctly. In the student's answer, there was a slight error in writing the analogy as shown in the figure above, which should be *x* as the price of cookies and *y* as the price of muffins. However, this error has corrected by writing the conclusion correctly.

Researchers also analyzed the results based on interviews with subjects who completed literacy questions, as follows.

Researcher: Can you please explain the important information you used to the problem?
Student: I used the information in Package A and Package B to find the price of 1 muffin and 1 cookie.
Researcher: Why didn't you use the information in packages C and D? Didn't it help you solve the problem?
Student: In my opinion, in packages C and D, the total price is not stated, whereas in packages A and B, the total price for each package is known, so it can be used to find the price of 1 muffin and one cookie.

Based on the interview excerpt above, it shows that Al is able to understand important information in the questions that help in solving the questions as seen from the subject Al being able to correctly explain important details in the questions along with the reasons. The absence of student difficulties in understanding important

information in the questions related to what is known and asked in the questions indicates that the epistemological obstacles indicator is not met (Hariyani et al., 2022).

Based on the procedural obstacles indicators and the analysis description above, subject Al did not show any procedural obstacles, with no difficulties found in understanding important information in the questions. The steps for solving the problem as a whole have been written correctly.

Technical and Operational Obstacles

Based on Figure 3. shows that overall, subject Al is able to carry out problem-solving operations correctly, and no errors were found in solving them, so the subject also found the final result of the solution correctly. This shows that

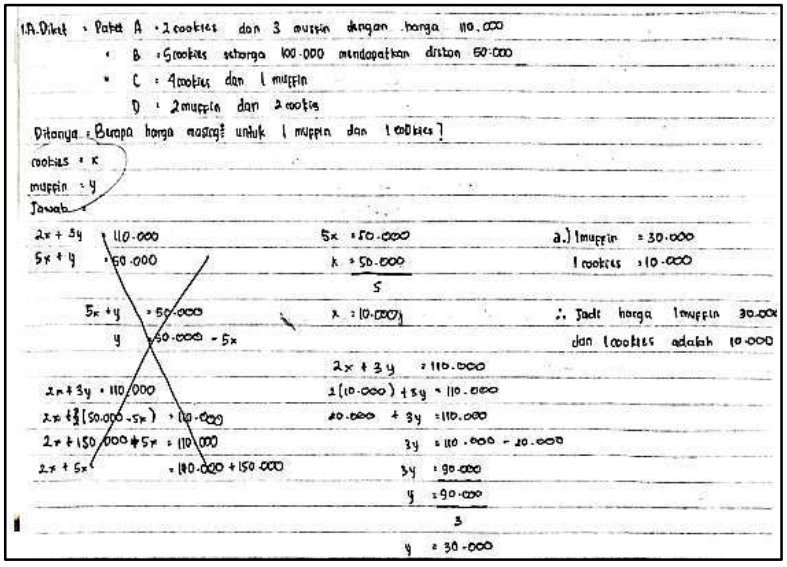

Figure 3. Results of the Al literacy test

the subject has a good understanding of the system of linear equations in two variables solution operation and is able to determine which operation is appropriate for the given problem so that the indicator of epistemological obstacles is not met (Hariyani et al., 2022). This statement is supported by the results of the interview analysis with the subject as follows.

Researcher: Now explain briefly what steps you took to solve this problem?

Student: First, use package B. So, it is known that 5 cookies are equal to 100.000 50.000, which means that 5 cookies are priced at 50.000, meaning 1 cookie is 10.000. Then, use package A because we found that 1 cookie is 10.000, which means that 2 cookies are 20.000 plus 3 muffins, the total is 110.000. This means that it is the same as 3 muffins equal to 110.000-20.000 equals 90.000. After that, there are 3 muffins, which means 90.000 divided by 3 equals 30.000. So the price of 1 cookie is 10.000 and 1 muffin is 30.000.

Researcher: Very good explanation. Then, are you sure or not about your answer?

Student: I am sure, ma'am.

Based on the interview excerpt above shows that Al has a good understanding of the concept of solving the given problem and has a good ability to determine the most appropriate

operation for the given problem. This is shown by the subject, who is able to provide an explanation related to the steps of solving the problem that have been explained well and correctly. Then, the subject also had full confidence in the answer he wrote.

Based on the technical operational obstacles indicators and the analysis description above, it shows that subject Al does not show any technical operational obstacles if, based on the results of the analysis of the subject's answers, he is able to write down the correct solution operations and is able to provide correct explanations related to the solution steps and has confidence in his answers.

Based on the analysis of the research data above, it shows that subjects with high algebraic thinking ability did not experience any epistemological obstacles because the subjects did not encounter conceptual, procedural, or technical operational obstacles, and the indicators of epistemological obstacles were not met. Subjects with high algebraic thinking ability had a good understanding of algebraic concepts, including mastery of all algebraic thinking processes (Rahmawati et al., 2019). Subjects with a good understanding of algebraic concepts also showed strong procedural abilities, including algebraic operations. This is due to the correlation between conceptual understanding and procedural understanding (Al-Mutawah et al., 2019). Consequently, no conceptual, procedural, or technical operational obstacles were found, which was also evidenced by the absence of difficulties when students solved mathematical literacy problems.

Based on the analysis of the research data, it shows that the subject was able to correctly solve the given problems in terms of conceptual understanding, operations, and technical procedures. In terms of conceptual understanding, the subject did not encounter any difficulties with the material on systems of linear equations in two variables, including solving the given problems, and had a good understanding of the application of systems of linear equations in two variables in real life. Therefore, it can be said that the subject had a good conceptual understanding of the systems of linear equations in two variables material. In terms of procedural understanding, the subject was able to know the key information in the questions, and the steps to solve the problems were correctly written and explained, indicating that the subject had a good procedural understanding of this material. In terms of technical operational understanding, the subject was able to determine and write the most appropriate solution operations for the given problems correctly and provide accurate explanations regarding the solution steps. This aligns with the research conducted by (Rahmawati et al., 2019), which showed that students with high algebraic thinking abilities are capable of understanding important information, analyzing, creating mathematical models, and solving mathematical problems correctly.

Conceptual, Procedural, Technical and Operational Obstacles of Student with Medium Algebraic Thinking Skills

Conceptual Obstacles

Figure 4 shows that Adrian already has a good conceptual understanding of the system of linear equations in two variables material, which is used as the basis for solving mathematical literacy problems. When viewed from the overall answers, the subject has been able to understand the problem correctly, write down the solution to the problem correctly and draw conclusions and reinterpret them in a real context. There are only a few errors in the interpretation of the problem solving as shown in the picture above, which should be "the price of 1 cookie is 10,000 and the price of 1 muffin is 30,000". However, these errors need to be more significant to indicate conceptual obstacles. This is supported by the interview with subject B1 as follows.

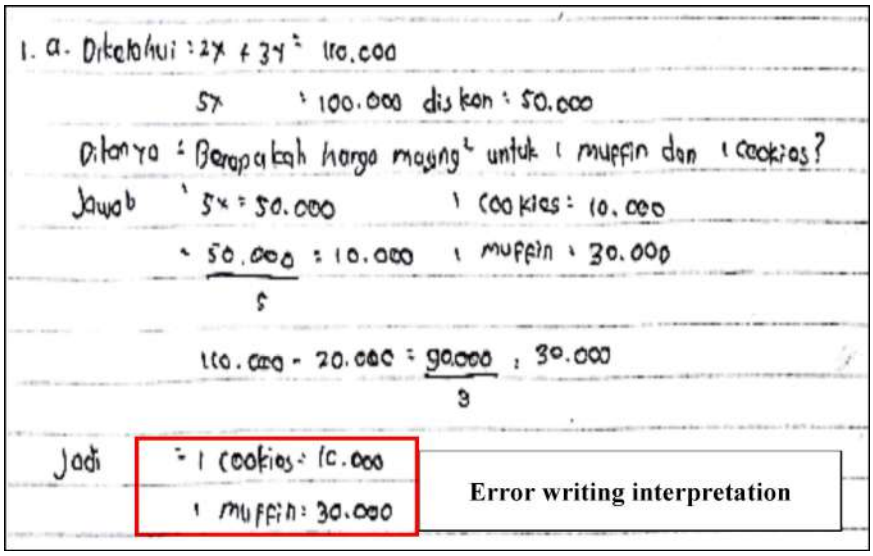

Figure 4. Results of the Bl literacy test

Researcher: Do you think the system of linear equations in two variables material is complex or not?
Student: I think it's quite good, ma'am
Researcher: From 1-10, where is your understanding of this SPLDV material?
Student: I think I'll give it 7, ma'am.
Researcher: Okay then, your understanding is quite good

Based on the interview excerpt above, it can be concluded that B1 understands the system of linear equations in two variables material well. This is indicated by S1, who stated that his understanding of system of linear equations in two variables material was quite good.

Researcher: Can you give another example of the application of system of linear equations in two variables material in life?
Student: What would it be, ma'am? Maybe buying books and pencils, ma'am?
Researcher: Yes, that's right, that's one of them.

Based on the interview excerpt above, it shows that B1 has a fairly good understanding of applying system of linear equations in two variables material in life. This is demonstrated by the subject's ability to provide another example of a real-life problem, even though the example given is not much different from the problem that was presented.

Based on the conceptual obstacles indicators and the analysis description above, it shows that subject B1 does not experience limitations in understanding the system of linear equations in two variables material and has a fairly good understanding of the material, especially related to its application in everyday life. So it can be said that no conceptual obstacles are found in subject B1.

Prosedural Obstacles

Based on Figure 5. shows that subject B1 has not been able to write the correct solution steps. Several errors were found in the students' answers, including the subject did not explicitly state the assumptions about the objects, specifically which objects were represented by the variables x and y used in the solution. Then, there is an error in writing the rules of algebraic operations, and the solution steps are written

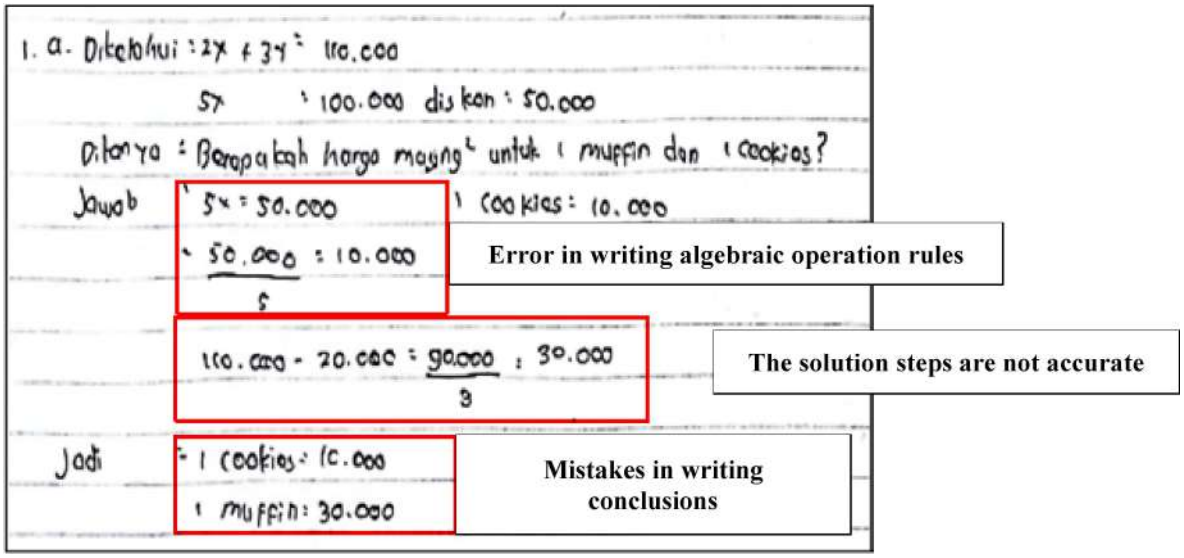

Figure 5. Results of the Bl literacy test

incorrectly, as shown in the image above. The inability of students to correctly carry out the solving process is an indication of a limitation in their procedural knowledge, which subsequently leads to procedural obstacles (Nahdi & Jatisunda, 2020). Then, in writing, the conclusion is also not quite because it is not written directly as "price".

Researchers also analyzed the results based on interviews with subjects who completed literacy questions.

Researcher: Can you explain what information is needed to solve this question?
Student: The information I use is numbers (i) and (ii)

Based on the interview excerpt above, it shows that B1 has been able to understand and determine important information in the questions that help in solving the questions. So it can be said that there was no difficulty found in students understanding important information in the questions related to what is known and asked in the questions.

Based on the procedural obstacles indicators and the analysis description above, it shows that the BI subject experienced procedural obstacles which are described from several errors made by the subject in the process of solving the problems he wrote, including in writing the conclusions and interpretations written by the subject even though the subject was able to understand the important information in the questions.

Technical and Operational Obstacles

Based on Figure 6. if viewed as a whole, the answer of subject B1 is able to perform problem solving operations quite well. However, errors were found in the solving operations, as shown in the figure above, which shows that the subject was not careful in writing it so that the answer given seemed to be wrong even though, in fact, the final answer obtained was correct. This can also happen if the understanding of the concept of algebraic operations is not good. However, the subject could determine which operation was appropriate for the given problem based on the steps written, even though they were not written completely.

The researcher also analyzed based on interviews with subjects in solving literacy problems as follows.

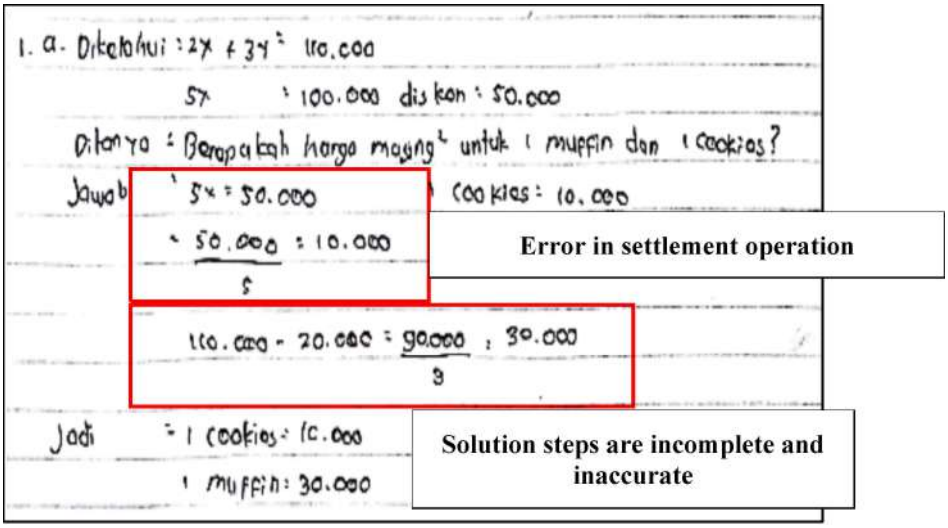

Figure 6. Results of the Bl literacy test

Researcher: Now can you please explain how you did it?

Student: First, what was asked was the price of 1 muffin and 1 cookie. So I used package A to find the price of 1 cookie. 5 cookies cost 50.000 so 1 cookie is 10.000. Then put it into package A so I found that 3 muffins cost 110.000 minus 20.000 so 3 muffins cost 90.000 meaning 1 muffin is 30.000.

Researcher: Great, thanks for the explanation. So are you sure or not with these steps and your answers?

Student: I am sure, ma'am.

Based on the interview excerpt above, it shows that B1 has a good understanding of the concept of problem solving and in determining the most appropriate operation for the given problem. This is shown by the subject who is able to provide an explanation of the steps for solving the problem that have been explained well and correctly. Then the subject also has full confidence in the answers he wrote.

Based on the technical operational obstacles indicators and the analysis description above, it shows that subject B1 shows a little technical operational obstacles if based on the results of the analysis of the subject's answers because there were a few errors in the operations and completion steps that he wrote. However, the subject has been able to provide a correct explanation regarding the completion steps and has confidence in his answer.

Based on the analysis of the research data above, it was found that subjects with medium algebraic thinking ability experienced epistemological obstacles, specifically in the areas of procedural and technical operational obstacles. This is because the subjects still made errors in the problem-solving process and in writing conclusions, which are indicators of procedural obstacles. Additionally, minor mistakes were found in the operations and steps of problem-solving, indicating the presence of technical operational obstacles. This study reveals that subjects with medium algebraic thinking ability tend to have a fairly good conceptual understanding, though not yet perfect, leading to occasional errors when solving problems related to algebraic concepts. Therefore, improving conceptual understanding is necessary to minimize procedural and technical operational obstacles. This is supported by the statement from

(Al-Mutawah et al., 2019), which asserts that knowledge stems from conceptual knowledge.

Based on the analysis of the research data, it was found that the subject experienced limitations in procedural understanding, as indicated by several errors made during the problem-solving process, including in the conclusions and interpretations written by the subject. This suggests that the subject's ability to fully comprehend the given problems was not sufficiently developed. In terms of technical operational understanding, errors were identified in the subject's operations and steps in solving the problems. Subjects with medium algebraic thinking ability still faced challenges related to algebraic operations (Rahmawati et al., 2019). This is consistent with the findings of (Rahmawati et al., 2019), which indicate that students with medium algebraic thinking ability continue to struggle with algebraic thinking, including limitations in using and processing information to solve problems and interpreting final results in real-world contexts. Thus, the analysis indicates that subjects with medium algebraic thinking ability experience epistemological obstacles when solving mathematical literacy problems, particularly in the areas of procedural and technical operational obstacles.

Conceptual, Procedural, Technical and Operational Obstacles of Student with Low Algebraic Thinking Skills

Conceptual Obstacles

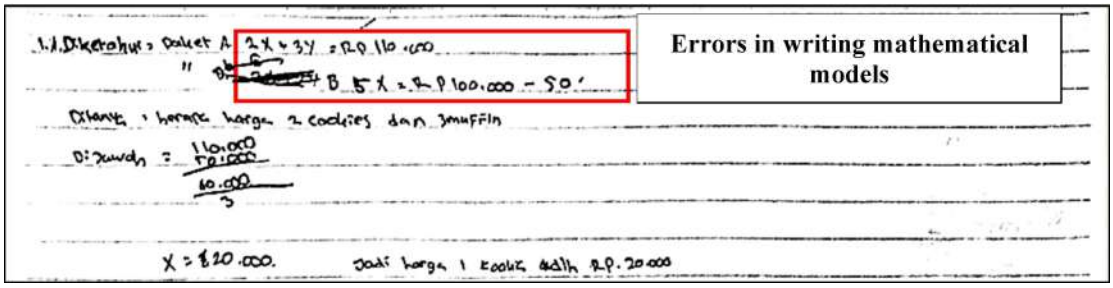

Figure 7. Results of the Cl literacy test

Figure 7 shows that Afgan lacks a conceptual understanding of the system of linear equations in two variables material. If, based on the overall answers of the subjects in the literacy test, the subjects have not been able to understand the problems given, all the steps for solving them need to be revised. The subjects' answers also show that the subjects have yet to be able to change the problems into mathematical forms, as shown in the figure above. This indicates that the concept of the system of linear equations in two variables.

Researcher: In your opinion, is the system of linear equations in two variables material difficult or easy?

Student: Actually, it isn't easy to other materials.

Researcher: Then, if your understanding of the system of linear equations in two variables material could be scored approximately out of 110, how much could your understanding of the system of linear equations in two variables material be scored?

Student: Maybe I'll give it 5, ma'am

Based on the interview excerpt above shows that C1 needs a better understanding of the system of linear equations in two variables material. This is evidenced by the subject's statement that the system of linear equations in two variables material is quite tricky and his self-

assessment of his knowledge of the system of linear equations in two variables material is also not good.

Researcher: Then, can you mention another example of the application of system of linear equations in two variables in life?

Student: Hmm, what would be another example, ma'am? I've forgotten a bit about that material. Sorry, ma'am, I'm not sure.

Based on the interview excerpt above, it shows that C1 does not yet have sufficient knowledge regarding the application of system of linear equations in two variables material. This is indicated by the subject's inability to provide another example of the application of system of linear equations in two variables in life.

Based on the conceptual obstacles indicators and the analysis description above, subject C1 experiences limitations in understanding the system of linear equations in two variables material. The subject is also unable to mention other examples of the application of system of linear equations in two variables material in life. Based on the analysis of answers and interviews, it can be concluded that the subject does not have a good conceptual understanding of the material. Therefore, it can be said that subject C1 has conceptual obstacles.

Prosedural Obstacles

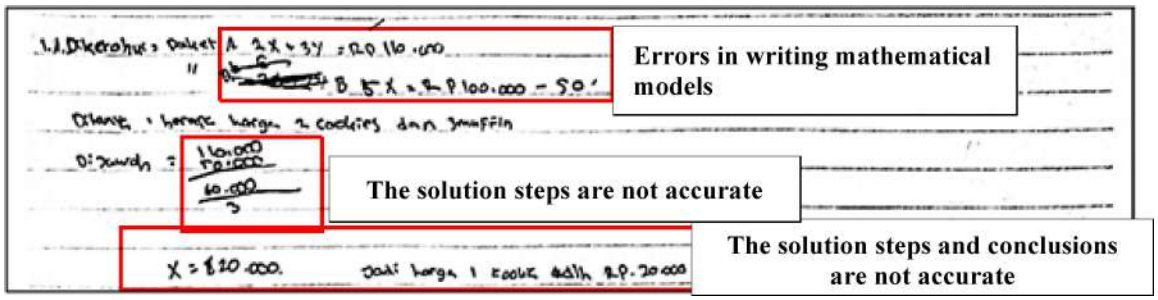

Figure 8. Results of the Cl literacy test

Based on Figure 8. it shows that subject C1 experienced *procedural obstacles* when viewed from the results of the subject's work. In the student's answers, several errors were found, including the subject not directly writing an example of an object, what object is represented by the variables x and y used in the solution. Then an error was found in writing a mathematical model that occurred due to the subject's limitations in compiling and using mathematical symbols in an algebraic concept. Procedural knowledge includes students' knowledge of using skills, techniques, and methods in solving mathematical problems (Nahdi & Jatisunda, 2020), so the subject's limitation in procedural knowledge indicates the presence of procedural obstacles. Then the solution step also shows that the subject does not understand the problem given and seems to write a solution that is not based on the problem given as shown in the picture above, so that the final results of the solution and the conclusions written are also wrong.

The researcher also analyzed the problem based on interviews with subjects solving literacy problems, as follows.

Researcher: Can you explain what important information you need to solve this problem?
Student: Point (1) is the same as (ii) which is the price of packets A and B.
Researcher: Now try to explain what is actually being asked in the question?
Student: I am asked to find the price of 1 muffin and 1 cookie.

Based on the interview excerpt above, it shows that C1 has been able to understand and determine important information in the questions that help in solving the questions. So there was no difficulty found in students understanding important information in the questions related to what is known and asked in the questions.

Based on the procedural obstacles indicators and the analysis description above, it shows that subject C1 experienced procedural obstacles, which were described from several errors made by the subject in the process of solving the problems he wrote, including from the written solution steps and the final results obtained even though the subject was able to understand important information in the problem. This indicates that although the subject is able to understand the important information in the problem, they experience limitations in interpreting and applying the understanding of the procedures for solving algebraic concepts. The subject's limitation in using knowledge to determine the appropriate solution procedure for the problem shows the presence of procedural obstacles (Nahdi & Jatisunda, 2020).

Technical Operational Obstacles

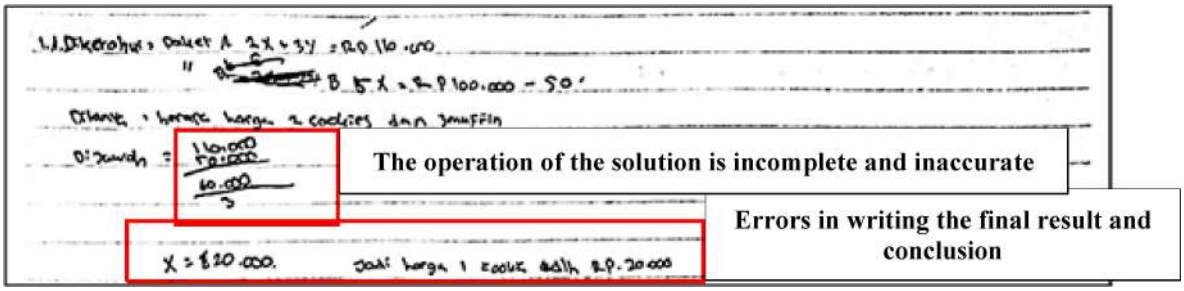

Figure 9. Results of the Cl literacy test

Based on Figure 9. shows that if viewed as a whole, the answers of subject CI have not been able to carry out problem-solving operations correctly and it seems that subject CI needs to have an understanding of the concept of problem-solving operations. The solution operations are also not written coherently and completely so that it cannot be analyzed in more depth how the purpose of the solution steps is as shown in the figure above. Student errors in carrying out solution operations have an impact on the final results and conclusions written by the subject which are also wrong. In general, it shows that the subject experiences epistemological obstacles, especially in the technical, operational obstacles section, because there are indicators of limited understanding related to the concept of solution operations and the ability to determine the appropriate operation for the problem (Hariyani et al., 2022).

Researchers also analyzed the results based on interviews with subjects who completed literacy questions, as follows

Researcher: Now explain the steps you took to solve this problem!
Student: *(SMILING)* I don't really know. I am confused about that.

Researcher: You are the one who did this, how come do you say that you are confused? Could you please explain to me?

Student: Make that $2x + 3y$ 110.000, $5x$ = 100.000 - 50.000 then 110.000 - 50.000 results 60.000 then divided by 3 so 1 cookie costs 20.000.

Researcher: So, is the variable you use to represent cookies x or y?

Student: Hehe, I don't know, Mom. It's difficult, mom. My friend helped me with this.

Researcher : Oh I see, that's fine. Does that mean you don't really understand what you're actually doing?

Student: Yes ma'am, I'm still confused.

Based on the interview excerpt above, CI does not have a good understanding of the concept of problem-solving operations and does not understand how to determine the most appropriate operation for the given problem. This is shown by C1 who was unable to explain the steps for solving the problem and stated that he still needed clarification in solving the problem and did not feel confident in the results of the solution he wrote.

Based on the technical operational obstacles indicators and the analysis description above, it shows that subject C1 experienced technical, operational obstacles if based on the results of the analysis of the subject's answers because errors were found in the completion operation and the subject was also not yet able to explain the completion steps and experienced confusion in completing it.

The analysis of the research data above shows that subjects with low algebraic thinking ability were found to have conceptual, procedural, and technical operational obstacles. This finding is supported by research (Rahmawati et al., 2019) , which shows that students with low algebraic thinking ability still need to be able to think algebraically at a sufficient level. The limited understanding of algebraic concepts indicates that the subject faced conceptual obstacles. When subjects experience conceptual obstacles, it tends to affect their procedural and technical operational understanding in problem-solving, as there is a correlation between conceptual and procedural understanding (Al-Mutawah et al., 2019). This results in the difficulties students face when solving mathematical literacy problems, as the foundation of the problem-solving process lies in a strong understanding of algebraic concepts and procedures.

Based on the analysis of the research data, it was found that the subjects were unable to solve the given problems correctly. The subjects needed to improve their understanding of concepts, operations, and technical procedures. Regarding conceptual understanding, the subjects made many errors in problem-solving, indicating a need for more solid understanding of algebraic concepts. In procedural understanding, several mistakes were identified in the subjects' problem-solving processes, including errors in the steps taken and the final results obtained. Although the subjects were able to explain key information in the questions, they faced challenges in writing, interpreting, and applying their procedural understanding of algebraic concepts, which became a primary factor contributing to the procedural obstacles encountered by the subjects. In terms of technical operational understanding, errors were found in the operations used to solve problems, and the subjects also needed help to explain the steps involved, leading to confusion in completing the tasks. Therefore, subjects with low algebraic thinking ability tend to have low mathematical skills. This aligns with research conducted by (Hajizah et al., 2021; Puspitasari et al., 2018), which shows that students with low mathematical ability experience difficulties in understanding problems and determining strategies for problem-solving, including the unclear writing of procedures and solution steps. Thus, the analysis indicates

that subjects with low algebraic thinking ability experience epistemological obstacles when solving mathematical literacy problems, particularly in the areas of procedural and technical operational obstacles.

Based on the description above, it can be analyzed that in students with high algebraic thinking skills, no epistemological obstacles were found because the subjects needed to experience conceptual, procedural, and technical operational obstacles, including the unfulfilled epistemological obstacles indicators. This is supported by research (Rahmawati et al., 2019); students with high algebraic thinking ability are able to understand important information, analyze, create mathematical models, and solve them correctly.When the subject can solve the problem correctly, this shows that the subject does not experience conceptual, procedural, or technical operational obstacles. In students with medium algebraic thinking skills, epistemological obstacles were found only in the procedural and technical operational obstacles sections. This is because the subject still needs to improve in the process of solving problems and writing conclusions which are included in the indicators of procedural obstacles. There are few things that could be improved in the operations and written solution steps which are included in the indicators of technical operational obstacles. Meanwhile, epistemological obstacles were found in all areas of students with low algebraic thinking skills, namely conceptual, procedural, and technical operational obstacles. This is supported by research (Hajizah et al., 2021), that students with low algebraic thinking ability tend to make mistakes in solving algebraic problems and have limitations in algebraic concepts. Limited understanding of algebraic concepts has an impact on the emergence of conceptual obstacles, procedural obstacles, and technical operational obstacles which also indicate epistemological obstacles experienced by the subject.

CONCLUSION

Based on the research results analyzed above, it can be identified that epistemological obstacles occur in solving mathematical literacy problems among students with medium and low algebraic thinking abilities, while students with high algebraic thinking abilities do not experience epistemological obstacles in solving mathematical literacy problems. Students with medium algebraic thinking abilities only experience procedural obstacles and technical operational obstacles, while students with low algebraic thinking abilities encounter conceptual obstacles, procedural obstacles, and technical operational obstacles in solving mathematical literacy problems. In the high algebraic thinking ability group, no conceptual, procedural, or technical operational obstacles were found, and the indicators of epistemological obstacles were not met. This is also indicated by the absence of errors in solving the given problems. In the medium algebraic thinking ability group, epistemological obstacles were found in the procedural obstacles section, as errors were still observed in the problem-solving process and the writing of conclusions. Subjects in the medium algebraic thinking ability group also experienced technical operational obstacles, as errors were found in operations and steps of problem-solving. In the low algebraic thinking ability group, epistemological obstacles were found in all areas, including conceptual obstacles, procedural obstacles, and technical operational obstacles. This occurred due to a limited understanding of algebraic concepts, which then affected the entire problem-solving process.

This study show differences in the characteristics of epistemological obstacles, particularly among students with medium and low algebraic thinking abilities, when viewed from conceptual obstacles, procedural obstacles, technical operational obstacles, and indicators of epistemological obstacles. The differences in the

characteristics of epistemological obstacles in each algebraic thinking ability group can serve as a reference for teachers to conduct evaluations and follow-ups in selecting strategies, methods, teaching approaches, and learning materials. These should be adjusted by considering the differences in student characteristics in each algebraic thinking ability category, especially in efforts to minimize the occurrence of epistemological obstacles as a way to improve the quality of learning and mathematical literacy skills, particularly among students with medium and low algebraic thinking abilities. This study can also serve as a reference and foundation for further research or development by exploring other perspectives or within a broader scope of similar studies. Future research can build upon this study by using different research frameworks to describe the occurrence of learning obstacles in solving mathematical literacy problems. Additionally, follow-up research can further this study by focusing on identifying methods or strategies to minimize the occurrence of epistemological obstacles in solving mathematical literacy problems, particularly from the perspective of algebraic thinking abilities, focusing on students with medium and low algebraic thinking abilities. This can complement the current research, as this study is limited to analyzing epistemological obstacles experienced by middle school students in solving mathematical literacy problems from the perspective of algebraic thinking abilities, without including solutions or follow-up actions regarding the epistemological obstacles encountered by students in solving mathematical literacy problems.

■ REFERENCES

Ainun, Y., Sridana, N., Kurniati, N., & Sarjana, K. (2024). *An analisis epistemological obstacle berdasarkan kesalahan menyelesaikan soal matematika materi segitiga siswa kelas VII SMP Negeri 3 Mataram Tahun Ajaran 2022/2023*. *Mandalika Mathematics and Educations Journal*, *6*(1), 26–37. https://doi.org/10.29303/jm.v6i1.6650

Allolayuk, S., Fm Ambotuo, V., Tomori, F., Kunci:, K., Aljabar, B., & Quotient, A. (2024). *Kemampuan berpikir aljabar dalam menyelesaikan masalah spldv ditinjau dari adversity quotient (aq) siswa smp negeri 2 pamona barat* [algebraic thinking ability in solving systems of linear equations in two variables (spldv) viewed from the adversity quotient (aq) of students at SMP Negeri 2 Pamona Barat]. *Jurnal Pendidikan Tambusai*, *8*(1), 2669–2680. https://doi.org/https://doi.org/10.31004/jptam.v8i1.12790

Al-Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: High school graduates work analysis and standpoints. *International Journal of Education and Practice*, *7*(3), 258–273. https://doi.org/10.18488/journal.61.2019.73.258.273

Badawi, A., Rochmad, & Agoestanto, A. (2016). *Analisis kemampuan berpikir aljabar dalam matematika pada siswa kelas VIII* [analysis of algebraic thinking ability in mathematics among eighth grade students]. *Unnes Journal of Mathematics Education*, *5*(3), 182–189. https://doi.org/https://doi.org/10.15294/ujme.v5i3.13100

Chan, J. Y. C., Ottmar, E. R., Smith, H., & Closser, A. H. (2022). Variables versus numbers: Effects of symbols and algebraic knowledge on students' problem-solving strategies. *Contemporary Educational Psychology*, *71*. https://doi.org/10.1016/j.cedpsych.2022.102114

Dewi, N. R., & Maulida, N. F. (2023). The development of stem-nuanced

mathematics teaching materials to enhance students' mathematical literacy ability through information and communication technology-assisted preprospec learning model. *International Journal of Educational Methodology*, *9*(2), 409–421. https://doi.org/10.12973/IJEM.9.2.409

Dewi, R., Riyadi, R., & Siswanto, S. (2022). Students' epistemological obstacles in statistical problems. *2nd National Conference on Mathematics Education 2021 (NaCoME 2021)*, *656*, 183–188. https://doi.org/https://doi.org/10.2991/assehr.k.220403.026

Fauziyah, A. N., & Masduki, M. (2023). *Eksplorasi kemampuan berpikir aljabar siswa sekolah dasar dalam menyelesaikan soal manipulasi numerik* [exploration of elementary school students' algebraic thinking ability in solving numeric manipulation problems]. *JMPM: Jurnal Matematika Dan Pendidikan Matematika*, *8*(1), 1–14. https://doi.org/10.26594/jmpm.v8i1.3626

Fauziyah, R. R., & Jupri, A. (2020). Analysis of elementary school students' ability on mathematical communication and mathematical representation. *Journal of Physics: Conference Series*, *1521*(3). https://doi.org/10.1088/1742-6596/1521/3/032080

Genc, M., & Erbas, A. K. (2019). Secondary mathematics teachers' conceptions of mathematical literacy. *International Journal of Education in Mathematics*, *7*(3), 222–237. www.ijemst.com

Hajizah, M. N., Wijayanti, D. A., & Darhim, D. (2021). Realistic mathematics education on teaching functions to develop algebraic thinking skills. *Journal of Physics: Conference Series*, *1869*(1). https://doi.org/10.1088/1742-6596/1869/1/012130

Hariyani, M., Herman, T., Suryadi, D., & Prabawanto, S. (2022). Exploration of student learning obstacles in solving fraction problems in elementary school. *International Journal of Educational Methodology*, *8*(3), 505–515. https://doi.org/10.12973/ijem.8.3.505

Hasanah, M., & Hakim, D. L. (2022). *Kemampuan literasi matematis pada soal matematika pisa konten quantity dan konten change and relationship* [mathematical literacy ability in pisa mathematics problems on quantity content and change and relationship content]. *Journal for Research in Mathematics Learning* , *5*(2), 157–166.

Isnaniah, & Imamuddin, M. (2020). Students' understanding of mathematical concepts using manipulative learning media in elementary schools. *Journal of Physics: Conference Series*, *1471*(1), 1–7. https://doi.org/10.1088/1742-6596/1471/1/012050

Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. *European Journal of Educational Research*, *10*(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467

Kusuma, D., Sukestiyarno, Y. L., Wardono, & Cahyono, A. N. (2022). The characteristics of mathematical literacy based on Students' executive function. *European Journal of Educational Research*, *11*(1), 193–206. https://doi.org/10.12973/eu-jer.11.1.193

Maarif, S., Setiarini, R. N., & Nurafni, N. (2020). *Hambatan epistimologis siswa dalam menyelesaikan masalah sistem persamaan linear dua variabel* [epistemological obstacles students face in solving systems of linear equations in two variables]. *Jurnal Didaktik Matematika*, *7*(1), 72–89. https://doi.org/10.24815/

jdm.v7i1.15234

Maknun, C. L., Rosjanuardi, R., & Jupri, A. (2022). Epistemological obstacle in learning trigonometry. *Mathematics Teaching Research Journal 5 SUMMER 2022*, *14*(2), 5–25.

Nahdi, D. S., & Jatisunda, M. G. (2020). Conceptual understanding and procedural knowledge: a case study on learning mathematics of fractional material in elementary school. *Journal of Physics: Conference Series*, *1477*(4). https://doi.org/10.1088/1742-6596/1477/4/042037

Pujiastuti, H., Utami, R. R., & Haryadi, R. (2020). The development of interactive mathematics learning media based on local wisdom and 21st century skills: Social arithmetic concept. *Journal of Physics: Conference Series*, *1521*(3). https://doi.org/10.1088/1742-6596/1521/3/032019

Purwanti, A. F., Mutrofin, & Alfarisi, R. (2021). *Analisis literasi matematika ditinjau dari kecerdasan matematis-logis siswa* [analysis of mathematical literacy in relation to students' logical-mathematical intelligence]. *Jurnal Ilmu Pendidikan Sekolah Dasar*, *8*(1), 40–57. www.jurnal.unej.ac.id

Puspitasari, L., In'am, A., & Syaifuddin, M. (2018). Analysis of students' creative thinking in solving arithmetic problems. *International Electronic Journal of Mathematics Education*, *14*(1). https://doi.org/10.12973/iejme/3962

Rahmawati, A. W., Juniati, D., & Lukito, A. (2019). Algebraic thinking profiles of junior high schools' pupil in mathematics problem solving. *International Journal of Trends in Mathematics Education Research*, *2*(4), 202–206. https://doi.org/10.33122/ijtmer.v2i4.137

Rohim, D. C., Rahmawati, S., & Ganestri, I. D. (2021). *Konsep asesmen kompetensi minimum untuk meningkatkan kemampuan literasi numerasi siswa sekolah dasar* [concept of minimum competency assessment to improve elementary school students' numeracy literacy skills]. *Jurnal VARIDIKA*, *33*(1), 54–62. https://doi.org/10.23917/varidika.v33i1.14993

Sari, N. P. N., Fuad, Y., & Ekawati, R. (2020). *Profil berpikir aljabar siswa smp dalam menyelesaikan masalah pola bilangan* [algebraic thinking profile of junior high school students in solving number pattern problems]. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *11*(1), 56–63. https://doi.org/10.15294/kreano.v11i1.22525

Siagian, M. D., Suryadi, D., Nurlaelah, E., & Prabawanto, S. (2022). Investigation of secondary students' epistemological obstacles in the inequality concept. *Mathematics Teaching Research Journal*, *106*(4), 5–25.

Sibgatullin, I. R., Korzhuev, A. V., Khairullina, E. R., Sadykova, A. R., Baturina, R. V., & Chauzova, V. (2022). A Systematic review on algebraic thinking in education. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(1), 1–15. https://doi.org/10.29333/EJMSTE/11486

Sidik, G. S., Suryadi, D., & Turmudi, T. (2021). Learning obstacle on addition and subtraction of primary school students: analysis of algebraic thinking. *Education Research International*, *2021*. https://doi.org/10.1155/2021/5935179

Stahl, N. A., & King, J. R. (2020). Studying your own school: an educator's guide to practitioner action research. *Journal of Developmental Education*, 26–28. https://doi.org/10.4135/9781483329574

Sulastri, R., Suryadi, D., Prabawanto, S., & Cahya, E. (2022). This content is covered by a Creative Commons license, Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0). Epistemological Obstacles on Limit and Functions Concepts: A Phenomenological Study in Online Learning. *Mathematics Teaching Research Journal*, *14*(5), 84–106.

Sunariah, L., & Mulyana, E. (2020). The didactical and epistemological obstacles on the topic of geometry transformation. *Journal of Physics: Conference Series*, *1521*(3). https://doi.org/10.1088/1742-6596/1521/3/032089

Töman, U., & Gökburun, Ö. (2022). What was and is algebraic thinking skills at different education levels? *World Journal of Education*, *12*(4), 8. https://doi.org/10.5430/wje.v12n4p8

Utami, R. E., Ekawati, C., & Handayanto, A. (2020). *Profil kemampuan berpikir aljabar dalam memecahkan masalah matematika ditinjau dari gaya kognitif reflektif siswa smp* [profile of algebraic thinking ability in solving mathematical problems viewed from the reflective cognitive styles of junior high school students]. *Jurnal Ilmiah Pendidikan Matematika*, *5*(1), 13–24. https://doi.org/https://doi.org/10.26877/jipmat.v5i1.5502