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Students' metacognition in solving non-routine problems

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Abstract

Students' metacognition abilities based on their aspects have different levels. Metacognition aspects had categorized into parts of awareness aspects, evaluation aspects, and aspects of regulation. This study aims to describe how students are metacognitive in solving non-routine problems based on awareness, evaluation, and regulation characteristics. This research is a descriptive qualitative study with a sampled class VIII A Junior High School Batik Special Program (PK) Surakarta, which consisted of six students. The instruments in this research are non-routine problems or tests, observation sheets, and interview guidelines. The questions validator in this research are two teachers and a Mathematics Education lecturer from the University of Muhammadiyah Surakarta. The data collection technique uses tests, observations, and interviews. The data analysis technique of research had carried out through three stages: data reduction, data presentation, and conclusion drawing. This study concluded that the student's metacognition of eighth grade in solving non-routine problems had not developed better. Only one student can ideally find the metacognition aspects of awareness, evaluation, and regulation. Compared to medium-capable students, students with high abilities can discover the metacognition aspects well. In comparison, students with low skills have not been able to find all indicators of metacognition. Based on the results, further research may discover students' obstacles in implementing metacognition for mathematical problem-solving.

INTRODUCTION

Humans in their lives will not be separated from thinking, receiving information, digging for information, storing data, and relaying information again if needed. The high level of understanding will affect how students understand the material taught. Cognition affects students' thinking activities (Izzatin et al., 2020). As they age, students' cognitive abilities grow from egocentrism gained from the theory of mind about mental states (Hacker et al., 2009). Cognitive thinking skills are related to students' different math problem-solving methods (Izzatin et al., 2020). The cognitive structure can develop if the pedagogical content knowledge is good (Nanna & Pratiwi, 2020). Witkin (1964) states that there are two groups of cognitive subjects identified, namely field-dependent (FD), which shows high dependence on its field, and field-independent (FI), which indicates low reliance in the area. According to Izzatin et al. (2020), students with field-dependent cognitive styles tend to think globally, while field-independent cognitive techniques in solving problems have been done analytically. Therefore, the student's cognitive style can affect his ability and construction of thinking in solving problems.

Metacognition is an activity of how humans think (Ishartono & Sufahani, 2019). Flavell, (1979) said that metacognition comes from declarative knowledge of cognition obtained from long-term memory. Metacognition is a problem-solving process done consciously by himself

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(Wong, 2007). Failure of the metacognition process can affect solving mathematical problems, especially finding solutions (Wulan et al., 2021). In another sense, metacognition has intended as a thinking processor that uses more of his cognition ability activity so that a person thinks about the knowledge and cognition abilities that exist in him. Successful problem solving requires the ability to understand issues. Swanson (1990) explained that metacognition means understanding and using problem-solving strategies in learning. Metacognitive awareness is essential in effective learning because it can improve students' cognitive skills and coordinate students' knowledge in devising reflective strategies to achieve goals (Howard et al., 2000). Flavell (1999) mentions metacognition, the ability of factors and interactions with methods that influence the outcome of cognitive knowledge. (Wren et al., 2011) suggests that an organization must be aware of the entire cognitive structure and characteristics of learning itself. Martinez (2006) means that metacognition is an essential problem-solving process for everyone because completion requires awareness of what has been done and the strategy's effectiveness. The knowledge students have about metacognition skills is called metacognition awareness (Yorulmaz et al., 2021)

The metacognitive component is the ability stored by a person and used when completing cognitive tasks involving thoughts, beliefs, and skills (Momeni, 2012). Huitt (1997) argues that metacognitive components are what is known and unknown and the regulations that discuss how we learn. In the provision of tasks and a person uses his metacognition ability, the process can be seen using awareness, evaluation, and regulation. The process is described in activities that show each of its components. According to Purnomo (2018), awareness activities according to the Polya's solving stage are students rethinking what is known, rethinking questions in problems and relating them, rethinking the steps to be done, and rethinking problem-solving descriptions. In addition, in the evaluation activities, students review how to answer issues, check the order of problem-solving, review answers, rethink whether or not problem-solving solutions are true, and revisit failures in problem-solving.

Meanwhile, in regulation activities by Polya's solving steps, students rethink problem-solving plans, rethink differences in problem-solving steps, rethink what steps to start solving problems and rethink how these steps are used in problem-solving. Different components are critical in the cognitive effort, and metacognitive knowledge strengthens problem-solving. Implementing cognitive actions can improve metacognitive experiences (Kuzle, 2013). This research uses aspects and characteristics of metacognition adopted from Purnomo et al. (2017). Table 1 depicts the aspect and indicators of metacognition.

Table 1. The Aspects and Indicators of Metacognitive

Metacognitive Aspects	Indicator
Awareness	- Read a given problem over and over again. - Attention to essential problems cases by underlining words that are considered keywords. - Substitute known information into a formula
Evaluation	- Double-checking the relationship of the known things to the things asked in mathematical problems - Make a connection between the answers obtained and the given problems
Regulation	- Establish the way to answer - Check the method used to answer problem questions

Metacognition is indispensable for students in solving math problems (Sutama et al., 2019). Since the enactment of online or online learning, students have been less given space to apply their metacognition skills. Meanwhile, problem-solving is not just to provide students experience how skills and problem-solving processes, but the main goal is to train students to think about what the student thinks (Elita et al., 2019).

The vision applied in mathematics education in Indonesia is to understand concepts and ideas that have been applied to solving routine and non-routine problems through the development of reasoning, communication, and relationships in mathematics and outside mathematics learning (Rahayuningsih et al., 2020). There are two types of problems in solving mathematical problems: routine problems and non-routine problems. Routine problems include applying the same mathematical procedures as newly learned, while non-routine problems, namely, arriving at the correct procedures, require deep understanding and thinking (Putri, 2018). Non-routine problems are problems in the completion step that require deep thinking and are unusual because the settlement procedure is not as straightforward as the methods taught in the classroom (Mayangsari & Mahardhika, 2018). Non-routine problems can improve the logical reasoning of learners (Suandito et al., 2013).

Metacognition has divided into three aspects or components: awareness, evaluation, and regulation (Wilson, 2004). He said awareness is related to the individual's awareness of problem solving and strategies used to solve problems. In comparison, regulation is guided by individuals' knowledge and skills to maximize the thought process.

Previous research related to student metacognition has been conducted. The study focused on developing instruments to measure students' metacognition in the first category. The instrument is 1) Essay questions (Sutama et al., 2019), 2) A questionnaire metacognition (Purnomo et al., 2017). The second category is research on the role of student metacognition. The study concluded that the role of student metacognition is to build a well-composed mathematical frame of mind (Anggo et al., 2014), helping strategies to improve students' cognitive abilities (Nugrahaningsih, 2012), building students' thinking skills to solve a problem (Lusiana et al., 2020). Metacognition also plays a role in controlling and building students' cognition so that thinking becomes more effective and efficient (Sholihah, 2016). The category of third is research that finds the dimensions of metacognition. The research suggests aspects of metacognition (Setyaningrum & Mampouw, 2020), metacognition knowledge (Kholid M. N.; Lestari, 2019), and metacognition skills (Yuwono, 2014). Figure 1 illustrates the research position.

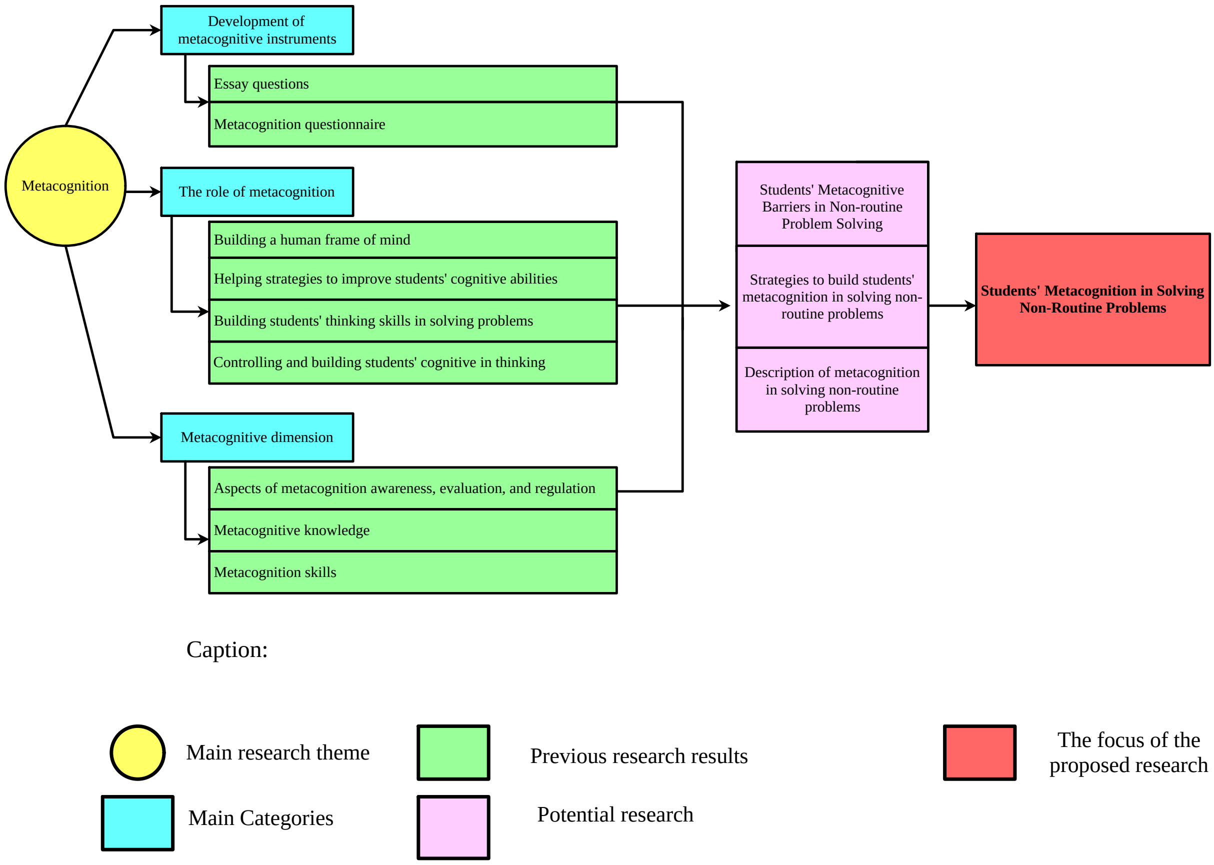


Figure 1. Research Position

In addition to reviewing existing research, researchers also have a foothold in previous research. In 2019, researchers managed to find that there were still some students with low ability categories in completing PISA-based mathematics on spatial material that did not meet all indicators of metacognitive knowledge and metacognitive skills (Kholid M. N.; Lestari, 2019). So that in 2019, researchers also conducted research related to students' metacognition in solving PISA-based mathematics on quantity content (Kholid et al., 2019), students' metacognition in solving PISA-based math problems on quantity content gained by metacognitive knowledge and metacognitive skills. This study proved that students with high mathematical skills, moderate mathematical skills, and low mathematical abilities had differences in the metacognition process. In the same year, researchers also conducted research on student metacognition in solving the problem of spatial analytic geometry reviewed from the adversity quotient (Kholid & Yuhana, 2019). This study concluded that the metacognition of the adversity quotient (AQ) climber type students met the most metacognition indicator compared to other types.

Meanwhile, students with the ability to metacognition adversity quotient (AQ) type camper have to solve problems based on solutions compiled by researchers. Still, they cannot completely write conclusions at the end of the answer. In addition, students with the ability to metacognition adversity quotient (AQ) type quitter can solve problems based on the stages compiled by researchers but cannot write conclusions at the end of the solution. Researchers have conducted many studies on student metacognition. Following up on this, Masduki et al. (2020) tested the efficacy and response of the student to metacognitive strategi in mathematics learning. The research became a guideline in the 2021 study. In 2021, research focused on how students metacognitive in non-routine problem-solving. Researchers also have plans to develop research on metacognition for 2022. This research is about student barriers to displaying metacognition. The research roadmap is illustrated in Figure 2.

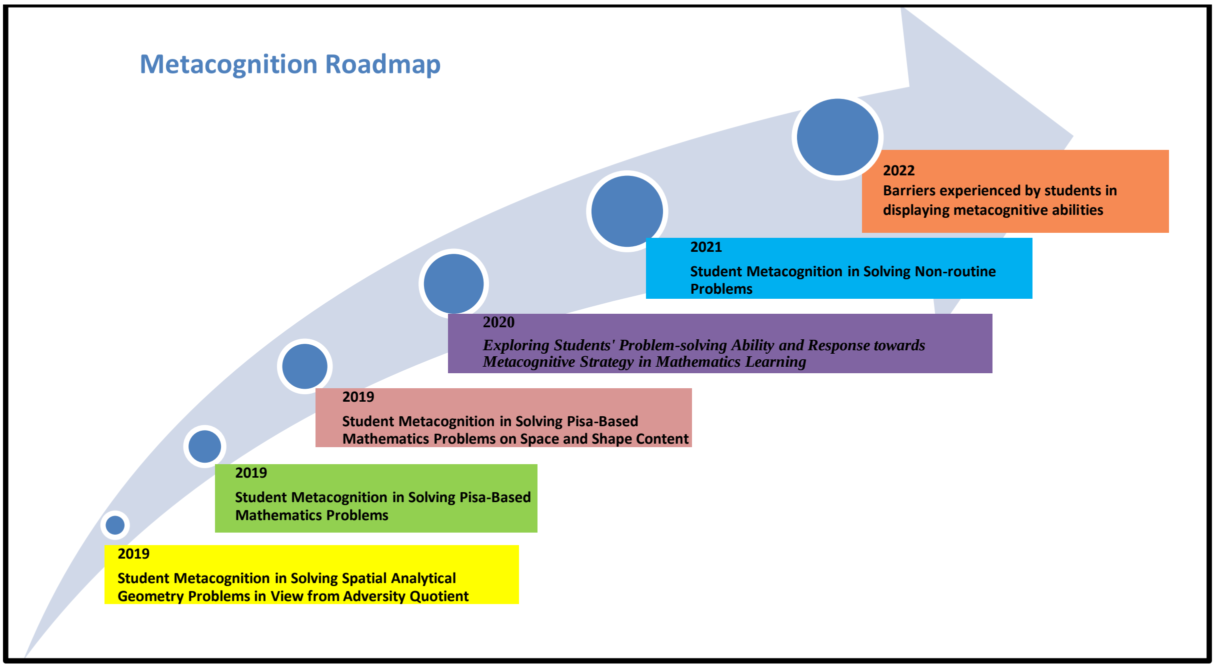


Figure 2. Research Roadmap

This study aims to describe how students are metacognitive in solving non-routine problems based on awareness, evaluation, and regulatory aspects. Based on the description, it is possible to classify student metacognition based on metacognition awareness, evaluation, and metacognition regulation. Therefore, researchers need to research students' thought processes in solving non-routine problems.

METHODS

This study describes the results of student metacognition analysis in solving non-routine problems based on awareness, evaluation, and regulation. This type of research is qualitative descriptive. According to Labuschagne (2015), qualitative research is data that is quoted directly and uses descriptions of situations, events, interactions, and behaviors observed. This research was conducted in August-December 2021 at Junior High School Batik Special Program (PK) Surakarta. This study sampled class VIII A Junior High School Batik Special Program (PK) Surakarta, as many as six students. The student samples are selected based on the characteristics of high-skilled, medium-capable, and low-ability students.

Before being tested on students, questions, validation sheets, and interview guidelines have been validated to determine whether the question is tested. Meanwhile, the subjects presented in this study are as many as three students based on these students' characteristics. The instruments used are non-routine questions related to number pattern materials, validation sheets, and interview guidelines. Validator questions from this study are two teachers and one lecturer of Mathematics Education, University of Muhammadiyah Surakarta. Table 2 explains examples of non-routine problems used in this research.

Table 2. Non-Routine Problems

Non-Routine Problems
They were given three consecutive numbers from an arithmetic sequence. The sum of the three numbers is 36, and the product of the three numbers is 1716. Determine the number and determine the most significant number!

The instruments used are non-routine test questions related to number pattern materials according to Figure 3, interviews, and metacognition questionnaires. Before non-routine questions are given to students, the question is validated to determine whether the question is tested on students. In addition, interview guidelines and metacognition questionnaires are also carried out validation process. Validator questions from this study are two teachers and one lecturer of Mathematics Education, University of Muhammadiyah Surakarta.

The data collection techniques used in this study are tests, interviews, validation sheets, and documentation. This research aligns with the data collection model (Miles, M. B., & Huberman, 1994). Interview guidelines were adopted from Purnomo (2018). In this study, students were asked to state the results of their thoughts in solving problems given orally. This result is done to think-aloud data. After working on the issue, the three subjects were interviewed to strengthen the study results.

According to Pandit (1996), data analysis is a Grounded Theory approach that uses breaking data, conceptualizing, and reconstituting data in new ways. Data analysis is composed, revised, and choreographed (Creswell, 2012). The data analysis technique of research results is carried out through three stages: data reduction, data presentation, and conclusion drawing. In data reduction, researchers choose essential points from the data according to predetermined indicators. Researchers present data descriptively that is arranged systematically. Meanwhile, the conclusion is obtained by how researchers take data from the evidence of the study results.

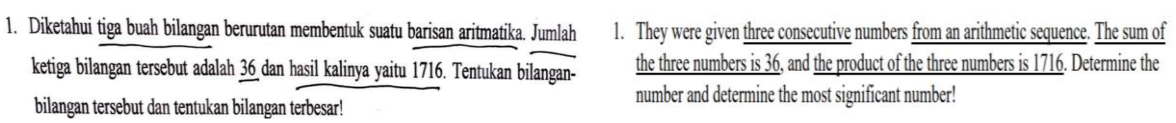
RESULTS AND DISCUSSION

In this section, research data will be presented from three subjects consisting of subjects with high ability (S-1), subjects with medium ability (S-2), and subjects with low ability (S-3). The issue is taken based on problem-solving skills that students can do. The following findings are discussed using comparison techniques with previous research findings.

High Ability Subject (S-1)

Subjects with high ability can read the problem given repeatedly in the question. Subjects with high ability can be seen directly that the issue reads the matter of the chirping times. Besides that, interview results stated that the subject had to read the question repeatedly to understand the problem given. In addition, this subject also underlines the words that are considered keywords in understanding the problem. This is indicated by underlining the keywords, namely three numbers, arithmetic sequences, the sum of the three numbers is 36, and the first result is 1716.

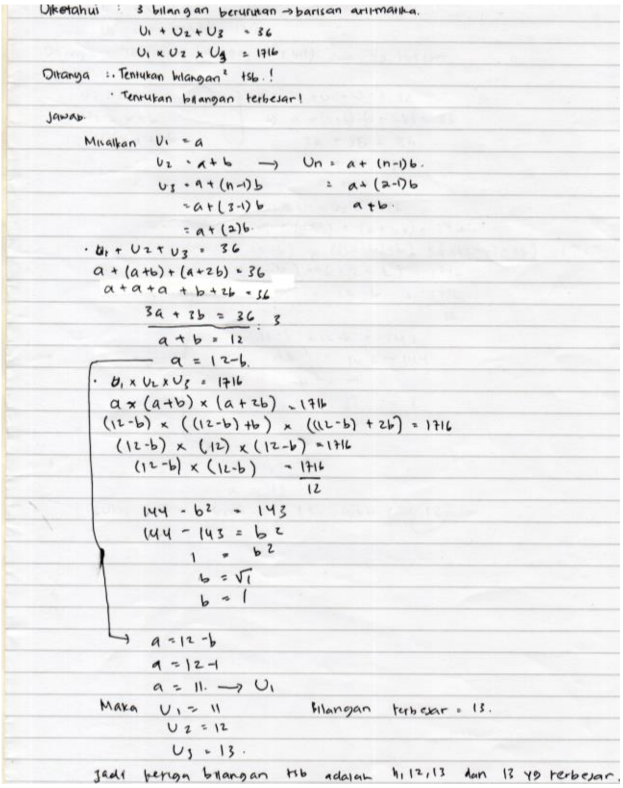
Translated version


1. Diketahui tiga buah bilangan berurutan membentuk suatu barisan aritmatika. Jumlah ketiga bilangan tersebut adalah 36 dan hasil kalinya yaitu 1716. Tentukan bilangan-bilangan tersebut dan tentukan bilangan terbesar!

1. They were given three consecutive numbers from an arithmetic sequence. The sum of the three numbers is 36, and the product of the three numbers is 1716. Determine the number and determine the most significant number!

Figure 3. High Ability Subject's Evidence in Underline Keywords

In answering questions, the Subject with high ability (S-1) has known substitute information in the formula. For example, when answering a question, S-1 writes down things known to be mathematical models. S-1 substitutions U1 as a, U2 substitutions as a+b, and U3 substitutions as a+2b. The subject wrote an equation, $U_1 + U_2 + U_3 = 36$, and $U_1 x\ U_2\ x\ U_3 = 1716$. Figure 4 illustrates the subject high ability answer sheet.


Diketahui : 3 bilangan berurutan → barisan aritmatika.
U1 + U2 + U3 = 36
U1 x U2 x U3 = 1716
Ditanya : • Tentukan bilangan² tsb.!
• Tentukan bilangan terbesar!
Jawab.
Misalkan U1 = a
U2 = a+b → Un = a+(n-1)b.
U3 = a+(n-1)b = a+(2-1)b
= a+(3-1)b a+b.
= a+(2)b.
• U1 + U2 + U3 = 36
a + (a+b) + (a+2b) = 36
a+a+a + b+2b = 36
3a + 3b = 36 : 3
a + b = 12
a = 12-b.
• U1 x U2 x U3 = 1716
a x (a+b) x (a+2b) = 1716
(12-b) x ((12-b)+b) x ((12-b)+2b) = 1716
(12-b) x (12) x (12-b) = 1716
(12-b) x (12-b) = 1716/12
144 - b² = 143
144 - 143 = b²
1 = b²
b = √1
b = 1
a = 12-b
a = 12-1
a = 11. → U1
Maka U1 = 11 bilangan terbesar = 13.
U2 = 12
U3 = 13.
Jadi ketiga bilangan tsb adalah 11, 12, 13 dan 13 yg terbesar.

Translated version

Known: three consecutive numbers → arithmetic sequence
U1+U2+U3=36
U1xU2xU3=1716
Asked: determine the numbers
find the most significant number
Answer:
For example U1=a
U2= a+b → Un = a+(n-1) b
U3= a+(n-1)b = a+(2-1) b
= a+(3-1) b = a+b
=a+2b
U1+U2+U3= 36
a + (a+b) + (a+2b) = 36
a+a+a+b+2b = 36
3a+3b= 36 :3
a+b= 12
U1xU2xU3= 1716
a x (a+b) x (a+2b) = 1716
(12-b) x (12-b+b) x (12-b+2b) = 1716
(12-b) x (12+b) = $\frac{1716}{12}$
144- b^2 = 143
144-143 = b^2
b = $\sqrt{1}$
b = 1
a = 12 -b
a = 12-1
a = 11 → U1
So, U1 = 11 the most significant number is 13
U2 = 12
U3 = 13
So, the three numbers are 11, 12, 13 and 13 is the largest number

Figure 4. High Ability Subject's Answer Sheet

Based on the analysis of test answer results and questionnaire results, the subjects with the high ability (S-1) can meet the indicator of double-checking the relationship of things known to the things asked in mathematical problems. This problem can be seen on the S-1 answer sheet that writes down the known things and things asked on the answer sheet completely and precisely. In addition, this subject can connect the answers obtained and the given problems. These results are reinforced from interviews and the solutions of subjects with high ability who write conclusions obtained from problem-solving results.

"Every time I do a math problem, I am used to writing known asked, answered and later if I have found the answer, I write the conclusion." In solving problems, a Subject with high ability (S-1) knows how to answer questions in mathematical problems. Subject with high ability is capable of double-checking how it answers problem questions. The interview results and the results of the correct S-1 answer establish the formula used.

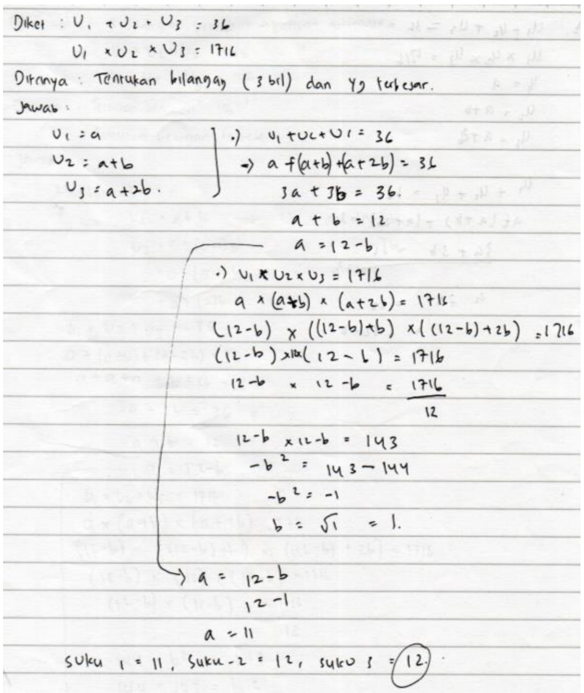
The questions given are different from the usual but still use arithmetic formulas. Non-routine problems can be solved using the arithmetic formula Un = a + (n-1) b, known as the formula. An equation is made and eliminated until the first quarter and the difference. After that, it is included in the Un formula again, and the results of the first tribe, the second tribe, and the third tribe will be obtained later."

Medium Ability Subject (S-2)

Subject with a medium ability (S-2), read the problem given repeatedly in the issue. The Subject reads a given problem frequently to understand a problem reinforced in interviews. So that in the problem presented, the topic with the ability to understand the problem and the Subject is confident that it can solve the given problem.

Subject with medium ability (S-2) does not underline the important things. However, this Subjek can write the sum of the three numbers and the result of the third time the number is known and the question, namely the most significant number. In addition, from the answer results, the Subject knows the steps to solve the problem. The Subject can precisely write the steps in detail. The evidence supports this opinion.

"The first step is to make a mathematical model, after which the known substitution into the formula un arithmetic. After that, it is eliminated until the first tribe results and so on." From the interview results above, that subject with a medium ability (S-2) knows how to solve mathematical problems. Figure 5 depicts the medium ability subject's answer sheet.



Translate Version

Known: U1+U2+U3=36
U1xU2xU3=1716
Asked: determine the numbers (3 numbers) and find the most significant
Answer:
U1 = a
U2 = a+b

→ U1+U2+U3= 36
→ a + (a+b) + (a+2b) = 36
3a+3b= 36
a+b= 12
→ U1xU2xU3= 1716
a x (a+b) x (a+2b) = 1716
(12-b) x (12-b+b) x (12-b+2b) = 1716
(12-b) x 12 (12+b) = 1716
(12-b) x (12+b) = $\frac{1716}{12}$
(12-b) x (12+b) = 143
$-b^2$ = 143-144
$-b^2$ = -1
b = $\sqrt{1}$ = 1

a = 12 -b
= 12 -1
a = 11

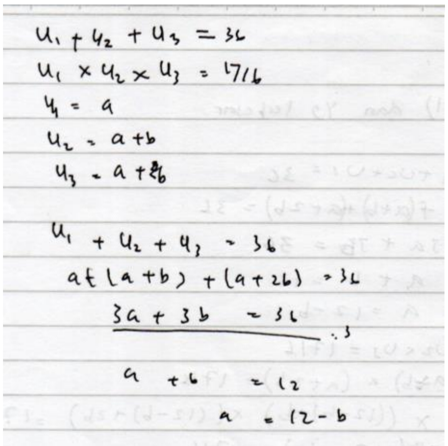
U-1= 11, U-2= 12, U3= 13

Figure 5. Medium Ability Subject's Answer Sheet

In addition, subjects with a medium ability (S-2) also substitute b into the formula a = 12-b. So can find the result is 11. S-2 does not always check the way used and does not write the conclusions of the problem-solving results. "I rarely check the way I use it is right or not because the time is limited. At the end of the answer, I often forget to write the conclusion of the answer, so rarely I write it."

Low Ability Subject (S-3)

Interviews with the subject of low ability (S-3) resulted in this subject not understanding the given problem, so S-3 read the problem two to three times. This research is reinforced in the interview that the subject believes that he can do the problem given when he has repeatedly read the issue. In the interview, S-3 also stated that he never underlined essential things in the non-routine problem and did not write down what was known and asked. "If I understand the same about it, I read directly write down how to get the result. But I never underlined the question, wrote known, asked". Figure 6 depicts the low-ability subject answer sheet.



Translated Version

U1+U2+U3=36
U1xU2xU3=1716
U1 = a
U2 = a+b
U3 = a+2b

U1+U2+U3=36
a + (a+b) + (a+2b) = 36
3a+3b= 36 :3
a+b= 12
a = 12 -b

Figure 6. Low Ability Subject’s Answer Sheet

From the results of the S-3 answer above, the S-3 cannot draw up a problem-solving plan precisely and precisely. It also looks like S-3 is confused in writing answers. On the answer sheet, S-3 can only create mathematical models. In addition, the S-3 can also provide U1, namely a, U2 is a+b, and U3 is a+2b. In solving the problem, S-3 can only substitute information into the formula until it gets a procedure from the first tribe. After getting the first-quarter result of 12-b, the S-3 forgot the way and concept used to continue solving the problem.
"I am still confused and forgot how to go next procedure. So I don't continue."

From these results, the Subject with low ability cannot solve the problem given appropriately, so the Subject also cannot write the proper problem-solving steps until writing a conclusion at the end of the answer. The results of the test data analysis show that the subject undergoes a metacognition process, namely awareness, evaluation, and regulation when solving non-routine problems. This result is in line with research conducted by Setyadi (2018) and Abidin (2014), which found that the subject's metacognition aspects are aspects of awareness, evaluation, and regulation when conducting the problem-solving process. But in this research, students met the aspects of metacognition. This research is in line with Setyaningrum & Mampouw (2020), which states that students experience a metacognition process in solving problems based on aspects of awareness, evaluation, and regulation. However, some metacognitive indicators cannot be optimal. However, not all optimally fulfilled indicators.

Only students with high abilities can solve problems accurately and precisely among the three subjects presented. This research is relevant to the research conducted (Sutama et al., 2019). Students with high skills can meet all aspects of metacognition, namely awareness, evaluation, and regulation. Students with high metacognition abilities can solve problems precisely and precisely. This result is relevant to the research (Sutama et al., 2019). Students with medium abilities can meet several indicators such as awareness, evaluation, and regulation, even though they do not meet all indicators. Students with low ability have difficulty solving problems, so they can only complete some awareness, evaluation, and regulation indicators.

This study is similar to that of Sumitro et al. (2019), which states the need to read repeatedly to understand the question in the issue. In the awareness aspect, the three students tend to understand the problem asked in the issue by reading the problem given repeatedly. In this process, the three students read the problem repeatedly to strengthen their thought process in determining the concept and the steps to be used in solving the problem. In addition, students can substitute known information into formulas. However, only students with high abilities can underline words that are considered keywords.

Subjects with high knowledge and medium abilities can use the information to plan problem-solving in the evaluation process. Students with high and medium abilities can understand what is known and problem questions in the evaluation aspect. On the other hand, students with low abilities cannot infer the information obtained. This result is in line with research by Fuady (2017).

Characterized regulation by the student can make a plan before solving a given problem. In regulation, students with high ability can establish a way to solve problems well. At the same time, students with low ability have not been able to establish the right way to solve non-routine problems. This problem is because students are used to routine issues. In comparison, students are less trained in solving non-routine problems that solve problems through several stages of thinking. The statement is relevant to Selan & Yunianta (2017) research. Subjects have difficulty in determining the concept. Students double-check whether the method used is correct or not. This result is relevant to Purnomo et al. (2017) research.

Students cannot immediately do problem-solving in solving mathematical problems, especially non-routine. Therefore, it takes understanding the problem repeatedly to solve the issue appropriately. However, with the metacognitive ability possessed by each student, non-routine problem solving can be translated even though it is not optimal. This result is from research conducted by Kuzle (2013). In the study, Kuzle (2013) suggests that metacognition ability can encourage a person to know his position in the problem-solving process, help understand a given problem, and help achieve the goals carried out in the problem-solving process.

Data collection in this study was carried out at the peak of the Covid-19 pandemic, while data collection must be carried out face to face with the research subjects. Therefore, researchers cannot meet as many students as possible. In this study, researchers were only able to take six subjects. The subjects' limitations may result in a lack of galore data. Researchers suggest that similar studies can improve the number of subjects as possible so that the data obtained is galore. The more research data used, the more valid the conclusions obtained from the results.

CONCLUSIONS

Based on the research results and the presentation of discussions, the three students have carried out the metacognition process. However, student metacognition in solving non-routine problems has not developed correctly. Only one student can appropriately and perfectly meet the aspects of metacognition awareness, evaluation, and regulation. Students with high ability categories (S-1) can meet the metacognition aspects of awareness, evaluation, and regulation regularly compared to students with medium ability categories (S-2) and students with low ability categories (S-3). Reading problems repeatedly and substituting the information obtained into a formula can be the average ability of metacognition awareness seen in students. In the metacognition evaluation aspect, students with low knowledge (S-3) have not been able to meet all indicators. Similarly, in the element of metacognitive regulation, students with a low ability (S-3) have not been able to meet all regulatory indicators. The next research may discover students' obstacles in implementing metacognition for mathematical problem-solving based on the results.

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AUTHOR CONTRIBUTIONS STATEMENT

MNK is a research coordinator. He contributes to developing ideas and methods. AA is responsible for developing the theory, designing the instruments, and collecting and analyzing the data.

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