VALIDITY OF METACOGNITIVE AWARENESS INVENTORY AS A MEASURING TOOL FOR METACOGNITIVE ABILITY IN MATHEMATICS PROBLEM SOLVING

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ABSTRACT

Purpose: The purpose of this study was to explore various theories about metacognition, especially the measurement of metacognition using the Metacognition Awareness Inventory (MAI) and its relation to problem solving. The goal of this research is to describe the validity of the metacognition ability instrument in solving mathematical problems that require metacognition awareness.

Theoretical Framework: Problem solving is an essential part of the mathematics learning process. Metacognition becomes an important issue along with the trend of 21st century learning. Metacognition is important in achieving student cognitive learning outcomes, specifically in increasing the effectiveness of learning strategies. Many methods have been used to assess metacognition, including questionnaires, interviews, analysis of thinking-aloud protocols, observations, awareness-raising tasks, diaries, and autobiographies. The Metacognition Awareness Inventory is one tool for determining the level of student metacognition (MAI).

Method: Various studies related to metacognition have been carried out. This is a descriptive leather research to assess and obtain a valid quality instrument to characterize metacognitive ability in solving mathematical problems. Five Evaluation Experts in Mathematics Education validated the instruments. Expert judgment is used to validate constructs using the Objective Concurreence Index assessment. MAI are also empirically validated by using 157 high school students as respondents.

Results: According to the results and research findings, MAI has eight indicators: 1) declarative knowledge, 2) procedural knowledge, 3) conditional knowledge, 4) planning, 5) information management, 6) monitoring, 7) debugging, and 8) evaluation. Cronbach’s alpha = 0.671) was declared reliable for measuring students’ metacognitive awareness. To obtain a truly valid instrument, several points of the MAI statement on the components must be improved: (1) procedural knowledge; (2) planning; and (3) information management. Furthermore, performance assessment through student activities or activities during learning is required to confirm MAI results and students’ metacognitive knowledge.

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Conclusions: MAI meets the construct validity criteria, especially in terms of content validation and internal consistency (reliability), by maintaining 51 statements from the original questionnaire. Overall, MAI that has been compiled is valued valid and reliable to be used as a metacognition assessment instrument in solving mathematical problems. It can be concluded that the MAI is a valid instrument in measuring metacognition in problem solving.

Keywords: validity, metacognitive awareness inventory, measuring tool, metacognitive ability, mathematics problem solving.

VALIDADE DO INVENTÁRIO DE CONSCIÊNCIA METACOGNITIVA COMO FERRAMENTA DE MEDIÇÃO PARA HABILIDADE METACOGNITIVA NA RESOLUÇÃO DE PROBLEMAS MATEMÁTICOS

RESUMO

Propósito: O objetivo deste estudo foi explorar várias teorias sobre a metacognição, especialmente a medição da metacognição usando o Inventário de Consciência da Metacognição (MAI) e sua relação com a resolução de problemas. O objetivo desta pesquisa é descrever a validade do instrumento de habilidade de metacognição na resolução de problemas matemáticos que requerem consciência metacognitiva.

Estrutura Teórica: A resolução de problemas é uma parte essencial do processo de aprendizagem de matemática. Metacognição se torna uma questão importante junto com a tendência de aprendizagem do século 21. A metacognição é importante para alcançar os resultados de aprendizagem cognitiva do aluno, especificamente no aumento da eficácia das estratégias de aprendizagem. Muitos métodos têm sido usados para avaliar a metacognição, incluindo questionários, entrevistas, análise de protocolos de pensamento em voz alta, observações, tarefas de sensibilização, diários e autobiografias. O Inventário de Consciência de Metacognição é uma ferramenta para determinar o nível de metacognição do estudante (MAI).


Resultados: De acordo com os resultados e os achados da pesquisa, o MAI tem oito indicadores: 1) conhecimento declarativo, 2) conhecimento processual, 3) conhecimento condicional, 4) planejamento, 5) gerenciamento de informações, 6) monitoramento, 7) depuração e 8) avaliação. O alfa de Cronbach = 0,671 foi declarado confiável para medir a consciência metacognitiva dos alunos. Para obter um instrumento verdadeiramente válido, vários pontos da declaração MAI sobre os componentes devem ser melhorados: (1) conhecimento processual; (2) planejamento; e (3) gerenciamento de informações. Além disso, a avaliação de desempenho através de atividades estudantis ou atividades durante a aprendizagem é necessária para confirmar os resultados do MAI e o conhecimento metacognitivo dos alunos.

Conclusões: O MAI atende aos critérios de validade do constructo, especialmente em termos de validação de conteúdo e consistência interna (confiabilidade), mantendo 51 declarações do questionário original. No geral, o MAI que foi compilado é válido e confiável para ser usado como um instrumento de avaliação de metacognição na resolução de problemas matemáticos.
Pode-se concluir que o MAI é um instrumento válido para medir a metacognição na resolução de problemas.

**Palavras-chave:** validade, inventário de consciência metacognitive, ferramenta de medição, capacidade metacognitive, resolução de problemas matemáticos.

### 1 INTRODUCTION

Problem-solving is an essential part of the mathematics learning process. The problem-solving process allows students to gain experience by applying what they already know. Students must manage their minds well when solving math problems by utilizing the knowledge they already have, controlling and reflecting on the process of their own thinking, because what they think can help them solve problems. This awareness of one's own thought process is known as metacognition. Metacognition and problem solving are two interconnected concepts. Metacognition can assist students in solving existing problems.

Metacognition is a critical component of problem solving (Wismath, Orr, & MacKay, 2015). Metacognition occurs when people encounter new problems, uncertainties, or questions (Carr, 1994). Metacognition is an important aspect of problem solving because it can assist problem solvers in recognizing a problem that needs to be solved, defining the problem, and understanding how to achieve a goal or solution (Kuzle, 2013).

According to (Mevarech & Fridkin, 2006), students must have good metacognitive skills in addition to good cognitive skills when analyzing problems, identifying, selecting appropriate solutions, and evaluating the entire problem solving process. According to (Hodosyova, Útla, Vanyová, Vnuková, & Lapitková, 2015), metacognition emphasizes the importance of conscious control of the cognitive mind during problem solving and the construction of new knowledge schemas, so that metacognitive abilities can help students develop their understanding. The results of the research by Irawan, Priatna, Gustini, & Mulyani (2023) show that curriculum changes and innovations are oriented towards three things; First, the absorption of graduates in employment (referring to the Indonesian national qualifications framework); second, the flexibility of the learning process (based on borderless learning); the third gets international recognition (international certification or accreditation).

Individuals with mathematical competence can be produced through problem solving activities, according to (Mokos & Kafoussi, 2013). Problem solving is a skill and...
knowledge-based activity. Problem solving can be viewed as a cognitive process that necessitates mental effort and concentration because it entails gathering relevant information, identifying information, analyzing information, and finally making decisions (Waskitoningtyas, 2015).

Students' problem-solving thinking processes are what aim to train and familiarize students in finding the right strategy. This is closely related to metacognitive abilities. According to (Costa, 1987) metacognition is the ability to plan a strategy to generate the information needed to solve a problem, determine the strategic steps to be taken, and reflect on and evaluate the productivity of thinking skills. According to this definition, metacognition skills are abilities to devise a strategy for problem solving.

Metacognition is important in achieving student cognitive learning outcomes, specifically in increasing the effectiveness of learning strategies. One factor that can improve student achievement is metacognition in problem solving. Improving metacognition skills in math problem solving is equivalent to increasing student achievement; sometimes, even if students' initial abilities are low, if students have metacognitive abilities in math problem solving, they will force themselves to understand the lessons being taught (Schoenfeld, 1987).

According to (Koutselini, 1995), metacognition is a person's self-awareness of the thinking and learning processes he engages in, including his strengths and weaknesses, what he has not known and done, including determining whether his cognitive goals have been met or not, and how to use effective strategies that assist him in remembering information, thinking, learning, and problem solving. Metacognition is defined by (Schraw & Dennison, 1994) as "awareness and monitoring of one's own thoughts and performance in tasks," or "thinking about one's own thoughts." Metacognition is defined by (Flavell, 1979) as the active monitoring, proper control, and regulation of information processing activities in cognitive processes with human or non-human environments that occur continuously.

Anderson & Krathwohl (2001) classify metacognition into three types of knowledge: strategic knowledge, cognitive task knowledge, and self-knowledge. Strategic knowledge is knowledge of general learning, thinking, and problem-solving strategies. Knowledge of cognitive tasks includes understanding when and why strategies are used correctly. Self-awareness and belief in students' cognitive and learning strengths and weaknesses are examples of self-knowledge.
According to the findings of (Kapa, 2002) research, a learning environment that provides metacognitive support at each stage of the problem-solving process is significantly more effective than a learning environment that only provides metacognitive support at the end of the process. Magiera & Zawojewski (2011) identify and characterize contexts related to metacognitive activities, which are coded as metacognitive awareness, metacognitive regulation, and metacognitive evaluation. Mokos & Kafoussi (2013) investigated the spontaneous emergence of fifth-grade students' metacognitive monitoring and control functions while solving three types of mathematical problems: open-ended, authentic, and complex. Kuzle (2013) also describes the problem-solving behavior of two teacher candidates when solving non-routine geometry problems on their own.

Rompayom, Tambunchong, Wongyounoi & Dechsri (2010) that a common problem encountered in metacognition research is the inadequacy of techniques to measure metacognition underscores the importance of having metacognition measurement instruments available. Many methods have been used to assess metacognition, including questionnaires, interviews, analysis of thinking-aloud protocols, observations, awareness-raising tasks, diaries, and autobiographies. All instruments have benefits and drawbacks; for example, using interview and think-aloud techniques is not appropriate for students with verbalization disabilities; using questionnaires is easier to administer with a large number of students but may: (1) fail to provide in-depth analysis, (2) lack specificity and contextualization, and (3) contain problematic words (Phan, 2006).

The Metacognition Awareness Inventory is one tool for determining the level of student metacognition (MAI). MAI encompasses all aspects of metacognition and is divided into two parts: knowledge of cognition (which includes declarative knowledge (DK), procedural knowledge (PK), and conditional knowledge (CK)) and control or cognition control (which includes planning (p), management Information Management (IMS), Monitoring of Understanding (CM), Correction Strategy (DS), and Evaluation) (E).

Diagnostic tests to assess cognitive abilities related to metacognition (e.g., information visualization and diagram interpretation) provide a number of metacognitive skills (Lestari, Rohaeti, & Purwasih, 2018), whereas (Veenman, 2012) claims that task performance is more effective for assessing metacognitive ability. According to
(Rompayom, Tambunchong, Wongyounoi & Dechsri: 2010), metacognitive assessment necessitates appropriate content context for the achievement of metacognitive goals. Because the context must be understood or not be completely foreign, the material presented must be neither too easy nor too difficult for students to understand. Assignments enable students to see and develop conceptual understanding.

It is important to develop instruments to characterize metacognitive knowledge in mathematical problem solving. Herscovitz et al. (2012) explained that metacognitive abilities in learning must be focused on constructing knowledge through rational relationships between authentic experiences and the material being studied. This statement is in accordance with the characteristics of problem solving which emphasizes students' thinking scientifically. The expected result in the future is to obtain a portrait of students' metacognitive abilities using instruments developed in learning so that they can become a reference for providing appropriate stimuli in the learning process so that the potential for metacognitive abilities can be optimized.

Based on the instrument development work of Corebima (2009) and Rompayom (2010), as well as the research findings of Scraw & Moshman (1995), a much more effective instrument to test metacognitive skills is still required. The author simply explains the procedure and results of instrument validation in this article. The instrument in question is the MAI, which was adapted from the findings of Scraw and Dennison, Corebima, and Rompayom's research.

2 THEORITICAL FRAMEWORK

Individual students' knowledge of their thinking, self-evaluation, and self-monitoring are assessed using metacognition (Faradiba et al., 2019). Metacognitive talents will motivate pupils to better their learning outcomes. Good metacognitive abilities are associated with higher levels of learning accomplishment, and vice versa (Zulfayanto et al., 2021). Metacognitive techniques are methods for cognitively controlling one's own activities and understanding the purpose of cognition. This approach aids in the organization of learning, particularly in determining learning outcomes (Pertiwi & Nindiasari, 2022).

Assessing one's level of metacognitive awareness, according to (Scraw & Dennison), is part of the process of gaining metacognitive awareness. The metacognition awareness inventory (MAI) is one tool that can be employed. MAI encompasses all
aspects of metacognition, which is divided into two parts: knowledge about cognition (DK), procedural knowledge (PK), and conditional knowledge (CK)) and control or regulation of cognition (P), management information management (IMS), comprehension monitoring (CM), correction strategies (DS), and evaluation (E). The Metacognitive Awareness Inventory (MAI) is a metacognitive awareness inventory used to assess cognitive knowledge (declarative knowledge, procedural knowledge, conditional knowledge) and knowledge regulation (planning, monitoring, evaluating, debugging strategies, and management information strategies).

Two factors emerged. Factor 1-Self-Regulated Learning (56.9%), reflects the use applicability and self-reinforcement, together with organization, generative elaboration, and anchoring elaboration. Metacognitively, they make use of planning and revision. Factor 2-Motivational (17.3%), privileges positive association, gradual approach, and applicability (Reyes, Luján, Rodríguez, Óscar, Jiménez, Antepara, Mendoza, Morales, Bustillos, Farías & Varela, 2023).

Rompayom et al. (2010) reported the construction of a metacognitive knowledge instrument, which divides metacognitive information into declarative knowledge, procedural knowledge, and conditional knowledge. The designed instrument incorporates cognitive activities and metacognitive knowledge questions. In Schraw & Denissson (2001) research, several earlier findings, such as cognitive regulation, hint to metacognitive activities that help manage one's thinking or learning. According to Schraw & Denisson (2001), metacognitive regulation entails the employment of numerous ways, such as resources, tactics, and excellent awareness. Planning, monitoring, and assessing skills are three types of abilities that play a significant role in managing student skills connected to the learning process (Balcikanli, 2011).

According to Veenman et al. (2012), cognitive regulation assessment can be done in three ways: prospective, contemporaneous, and retrospective. The prospective method is carried out by identifying general metacognitive skills before the learning task is given. In the implementation of these two instruments, individuals are asked to indicate how often a statement represents the behavior being studied, for example using a Likert scale. Answers are coded, and methods and metacognitive advantages are assessed. Furthermore, Veenman et al. (2012) claimed that the concurrent technique was carried out utilizing the Think A Loud Protocol analysis, in which students were instructed to orally indicate what they were thinking throughout the task. Individuals can be monitored
for text features, understanding, issues, and strategies using this approach. This strategy includes films to improve data validity and analyze metacognitive skill performance using an expert judgment process. The retrospective method is used after a performance, and it is aided by the use of movies and memory activation tools. Learners are expected to replicate the metacognitive skills they used throughout the performance.

All of these assessment approaches have advantages and disadvantages (Veenman, 2012). Questionnaires, for example, are used to examine big groups, whereas Think A Loud Protocol approaches are utilized to assess individuals. Furthermore, certain evaluation procedures are more difficult to master than others. The most crucial objective, however, is to choose the best evaluation method for assessing metacognitive knowledge and its skill components. Questionnaires are frequently used to evaluate metacognitive activities or strategies, but the results do not always correspond to actual behavioral measurements during task performance (Veenman, 2012).

Corebima (2017) created a novel method of testing metacognitive skills that is combined with an essay form learning outcomes test with cognitive levels C2-C6. The scoring is done with a specific rubric that measures metacognitive skills. The breadth of the rubric is limited; some categories of cognitive knowledge and cognitive regulation are not mentioned in the rubric design. Conditional knowledge is a category that cannot be referred to as cognitive knowledge, as is the category of cognitive regulation that cannot be referred to as information management techniques and debugging procedures.

According to Gunstone (2001), metacognitive assessments must provide material background that is relevant to the metacognitive outcomes' objectives. According to Rickey & Stacy (2000), it is difficult to separate metacognition from a cognitive perspective because it is an internal process that can be concluded based on overt behavior.

3 METHODOLOGY

The goal of this research is to describe the validity of the metacognition ability instrument in solving mathematical problems that require metacognition awareness. Metacognition Awareness Inventory is a metacognition awareness instrument (MAI). This is a descriptive leather research to assess and obtain a valid quality instrument to characterize metacognitive ability in solving mathematical problems.
By taking cultural elements into account, the MAI content assessment process includes class X high school students in Boyolali Regency. MAI was translated into Indonesian by a professional translator who had never read MAI. Back translation was performed by many specialists to determine whether the MAI translation findings remained equivalent to the original version. Professional linguists and mathematics education experts are involved in the MAI adaptation process to adjust the language, content, and use in the context of mathematical problem-solving.

Five Evaluation Experts in Mathematics Education validated the instruments. Expert judgment is used to validate constructs using the Objective Concruence Index assessment with the following parameters: (1) consistency between objective items and question items, (2) correct language that is communicated, (3) correct way to answer questions, and (4) suitability of assessment criteria. The outcomes of expert judgment are given as an Objective Concruence Index (IOC). Each expert examines each item and assigns a +1 if it is appropriate, a 0 if the expert is doubtful, and a -1 if it is not. The index value is calculated using the findings of this assessment (Osterlind, 1998).

The validator's value is used to calculate the average value of the validity and reliability of the developed instrument. The percentage agreement equation developed by Emmer, Edmund T & Gregg B. Millett (1970) is used to calculate the reliability of learning tools. An instrument is said to be reliable if it has a percentage agreement of 75%, or as much as 75% of the average score of the validator team in the valid category. Suggestions and feedback from validators are used to improve the instrument developed to obtain a tool for characterization of valid metacognition knowledge in terms of content and construct.

Metacognition knowledge instruments are also empirically validated by using 157 high school students as respondents. The trial's goal is to determine whether potential responders understand and can answer each item on the questionnaire, and the results are used to improve the MAI. The entire sampling strategy is utilized for validation because the greater the number of samples, the lower the error rate and the greater the generalization accuracy. The results of the empirical validation of the instrument were then analyzed using the IBM SPSS Statistics 23 software to determine the instrument's validity and validity. If (r > r Table), the metacognitive awareness instrument is valid, and if (0.6 1.0), it is reliable (Malhotra, 2011).
4 RESULTS AND DISCUSSION

The Metacognition Awareness Inventory (MAI) (Schraw & Dennison, 1994) was used in this study as the metacognition awareness questionnaire, with eight indicators: 1) declarative knowledge, 2) procedural knowledge, 3) conditional knowledge, 4) planning, 5) information management, 6) monitoring, 7) debugging, and 8) evaluation. In this study, the metacognition awareness instrument was empirically tested with 200 student samples.

The metacognition awareness instrument consists of 52 items divided into eight categories: 1) declarative knowledge (5 items), 2) procedural knowledge (5 items), 3) conditional knowledge (8 items), 4) planning (7 items), 5) management information (9 items), 6) monitoring (7 items), 7) debugging (5 items), and 8) evaluation (6 items).

The instrument's empirical validity was tested using 200 students from classes X and XI as respondents, not including those who participated in the trial. There were 157 completed questionnaires out of 165 female students (64.2%) and 92 male students (35.8%). Respondents were from high school classes X and XI in two sub-districts in Boyolali Regency.

Respondents in the validation study completed a longer questionnaire that took 30 minutes compared to the trial time of 20 minutes. The distribution of responses to the MAI questionnaire items is more diverse than the distribution of responses to the trial. This confirms that the large number of respondents (n=157) can contribute to the questionnaire's validity. The results of the analysis show that the items of procedural knowledge, planning, and information management are not yet valid and need to be improved, but the metacognition awareness questionnaire developed is declared reliable or feasible to use at the implementation stage, with a Cronbach alfa value of 0.671.

The adaptation of the MAI to Indonesian, which involved numerous phases of translation and evaluation, resulting in the MAI statements in Indonesian being equivalent to the points MAI original form. The instrument was put to the test on 257 pupils. The responses of respondents were distributed in a variety of ways. Several questionnaire items had a "strongly agree" answer, including declarative knowledge item 45, planning item 27, information management item 33, conditional knowledge item 23, conditional knowledge item 41, conditional knowledge item 55, evaluation item 11, evaluation item 21, and evaluation item 50, whereas information management item 43, information management item 7, and planning 3 received a "disagree" response. The researcher opted
to keep the number of items in the adapted MAI questionnaire the same because respondents could understand and fill in the statement items.

The researcher keeps all questionnaire items in order to enter the validation stage, both in terms of grammar and number of questionnaire items. Although some questionnaire items did not receive a "strongly disagree" response from respondents, this does not imply that the item is problematic because not the entire opinion scale was used. During the trial, the number of respondents was still insufficient to make decisions on the elimination of questionnaire items on the number of questionnaire items, limiting the variation of responses. Following analysis in a validation study with a much larger number of respondents, the decision to discard or retain items is made (Sugiyono, 2011).

Because the initial assumption of the questionnaire design was that there were correlated and uncorrelated variables, Schraw and Dennison produced six extracted components using the unrestricted factor analysis method, orthogonal and oblique rotations. The 6 components account for 78% of the variance. The extraction results differed depending on whether the factor analysis was performed using oblique or orthogonal rotation methods. Then, according to the theory that metacognition consists of two scales, a restricted factor analysis was performed, yielding two components: the first dominated by cognitive knowledge and the second by the domain of cognitive control. MAI Jr., the Turkish version, which was also validated, left 18 statements, which were later reduced to 15 items with four extracted components. This demonstrates that the MAI is not completely stable when tested on various respondents (Schraw & Dennison, 1994; Aydin & Ubuz, 2010).

One of the weaknesses of this study is the type of research. Qualitative research only describes the absence of an exhaustive statistical test. The research would be improved if it used a combination of quantitative and qualitative methods to delve deeper into the questionnaire items discovered through statistical analysis (Sugiyono, 2011).

This study also has a flaw in that many respondents did not complete the questionnaire. This demonstrates that respondents are having difficulty filling out the questionnaire completely. A specific time and location for completing the questionnaire is required so that respondents can concentrate on completing the questionnaire. Due to study weakness, the population where this research was conducted was unable to represent the entire population of students in Indonesia.
The success of conducting validity tests on the MAI questionnaire adapted to Indonesian is the research's strength. The MAI questionnaire, which was translated from Indonesian, met the content validation criteria, indicating that it is consistent with the concept of metacognition (Pett, Lackey & Sullivan, 2003).

In theory, construct validity can be determined by examining the characteristics of the questionnaire's content, response process, internal structure, linkages with other variables, and implications of utilizing the questionnaire. The MAI questionnaire validation procedure begins with linguistic adaptations and conceptual investigations relevant to the MAI's content. These two processes are critical because they can determine whether the Indonesian MAI is consistent with metacognition principles and content. All MAI statement items resulting from language adaptation adhere to the concept of metacognition and have been reviewed by a validation team comprised of Indonesian language experts, mathematics education experts, educational psychology experts, and educational evaluation experts (Howard, McGee, Shia & Hong; 2000).

Another construct validity criterion is that the questionnaire response process be investigated using active comments on each item of the questionnaire as well as interviews with a number of respondents who provided comments (qualitative research). By connecting students' metacognition scores or scores with other variables, such as student test scores, the relationship between questionnaire items and other variables can be investigated. Furthermore, more research is required to determine the impact or consequences of measuring students' metacognitive awareness levels, such as in collaborative digital learning.

Metacognition is concerned with mental processes and plays a role in the mental. The availability of the metacognition awareness instrument, which is the affective domain in the form of a questionnaire, is insufficient to fully understand a person's metacognition, so the use of the metacognition cognitive domain instrument is essential. As previously stated, MAI is a questionnaire with 52 statement items. The questionnaire failed to identify students' awareness and metacognitive skills. This viewpoint is supported by Pressley & Harris (2006) that monitoring and regulation are frequently integrated in real-world performance.

According to the results and research findings, MAI has eight indicators: 1) declarative knowledge, 2) procedural knowledge, 3) conditional knowledge, 4) planning, 5) information management, 6) monitoring, 7) debugging, and 8) evaluation. Cronbach's
alpha = 0.671) was declared reliable for measuring students' metacognitive awareness. To obtain a truly valid instrument, several points of the MAI statement on the components must be improved: (1) procedural knowledge; (2) planning; and (3) information management. Furthermore, performance assessment through student activities or activities during learning is required to confirm MAI results and students' metacognitive knowledge.

5 CONCLUSION

Based on the explanation above, MAI meets the construct validity criteria, especially in terms of content validation and internal consistency (reliability), by maintaining 51 statements from the original questionnaire. Overall, MAI that has been compiled is valued valid and reliable to be used as a metacognition assessment instrument in solving mathematical problems.

Based on the results of this study we recommend the need for efforts to bring the metacognition concept closer in solving mathematical problems in the learning process in schools so students have better metacognition awareness. Further research on MAI with respondents needs to be done more to better understand the concept of metacognition in solving mathematical problems.
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