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Analysis of Metacognitive Failures when Using ChatGPT in Solving Mathematical Problems: An Islamic Educational Perspective

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Abstract. *Mathematics contributes significantly to the advancement of various fields of science, knowledge, and technology. In today's digital transformation era, technology plays an essential role in shaping the way students think and learn. One of the most influential technological innovations in education is artificial intelligence (AI), exemplified by ChatGPT. However, the ease of accessing solutions through AI may reduce students' awareness of their own thinking processes and lead to a decline in independent reasoning. Therefore, this study aims to analyze metacognitive failures among first-year university students when using ChatGPT to solve mathematical problems through an Islamic educational lens. From an Islamic perspective, thinking (tafakkur) and reflection (tadabbur) are acts of worship that cultivate intellectual and spiritual awareness. Islam emphasizes the responsible use of knowledge and technology, guiding learners to maintain amanah (intellectual honesty), avoid ghurur (deceptive dependence), and practice muhasabah (self- reflection) in the pursuit of understanding. Metacognition, in this sense, extends beyond cognitive control to include moral and spiritual accountability before Allah. This study employs a qualitative approach with a descriptive exploratory design. The instruments used include mathematical problem-solving tests, MAI (Metacognitive Awareness Inventory) questionnaires, and open-ended interviews. The research stages consist of identifying the problem, determining the focus of the study, specifying data needs, collecting data, and analyzing data. The results reveal that three participants experienced distinct forms of metacognitive failure: S1 experienced metacognitive blindness, S2 experienced metacognitive vandalism, and S3 experienced metacognitive mirage, as they perceived warning signs that were not actually present. Viewed through Islamic education, these failures illustrate an imbalance between rational and spiritual awareness. Overreliance on AI tools without critical reflection may weaken ijtihad (independent reasoning) and hinder sincere learning (ikhlas). Therefore, integrating Islamic values such as tawakkul (trust in Allah after effort) and amanah ilmiyyah (intellectual integrity) can help students use technology ethically and purposefully in their quest for knowledge.*

Keywords*: Metacognitive, ChatGPT, Mathematical Problem Solving, First-Year Students*

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Introduction

Mathematics plays an important role in advancing and developing science and technology today. As evidence, mathematics contributes significantly to the advancement of various fields of science, knowledge, and technology. Studying mathematics is a discipline that develops ways of thinking, reasoning, logic, and argumentation, as well as helping in solving everyday problems (Laia & Harefa, 2021). The National Council of Teachers of Mathematics (NCTM) identifies

several skills students must have in learning mathematics, including problem-solving (Perdana & Isrokatun, 2019). Goos (2002) also states that it is important for students to have mathematical problem-solving skills, as these skills can help them solve mathematical problems. In today's digital era, technology plays a vital role. The digital transformation era is part of a broader technological process that applies digital technology to human life (Devianto & Dwiasnati, 2020). One of the products of technological advancement that has contributed most to digital transformation is artificial intelligence (AI) technology (Devianto & Dwiasnati, 2020). Artificial intelligence is a branch of computer science concerned with the representation, modeling, and storage of human intelligence in information technology, which can be used for decision-making (Dewi, 2020). One of the most widely loved artificial intelligence products is ChatGPT. ChatGPT (Generative Pre-trained Transformer) is a chatbot that processes natural language and can respond to human questions in text. The advantages of this application are that the answers provided appear systematic, the words and sentences are coherent, it is highly accurate, and it can remember previous conversations (Suharman, 2023).

ChatGPT has touched almost every aspect of human life, including education. Merentek, Usoh, Sonny, & Lengkong (2023) it is stated that ChatGPT is a technology-based learning tool currently popular in teaching and learning. The use of ChatGPT as a learning medium can increase students' enthusiasm because it offers many conveniences for searching and collecting information and extensive facilities across various fields of science. With the development of artificial intelligence (AI), such as ChatGPT, new concerns have arisen: the advancement of AI is not accompanied by adequate knowledge of how to use it. Therefore, the public needs to understand the uses of AI. In the academic realm of lectures, the development of AI could erode students' critical thinking and creative work. In a study by Salsabila, Ramadhani, & Husna (2024), 34% of participants used AI to support their studies, and 32% admitted to using ChatGPT to solve math problems. As many as 60% of questionnaire respondents agreed that the use of ChatGPT led to a decline in cognitive or thinking abilities.

Cognitive ability, according to Faradiba & Alifiani (2020), is a process that involves mental activity in general and is characterized by the representation of objects in an individual's mental image as ideas, responses, symbols, and values. Meanwhile, according to Baumanns & Rott (2023), knowledge about cognitive phenomena is called metacognitive, which can be simply interpreted as thinking and being aware of thinking. However, the metacognitive process does not always run smoothly; it is often hindered by obstacles, leading to what is called metacognitive failure (Alifiani, 2022). Goos (2002) describes metacognitive failure into three types, namely: 1) metacognitive mirage, described as metacognitive failure occurring when students ignore helpful strategies, change calculations that are correct, and reject correct answers, 2) metacognitive vandalism, described as occurring when a student solves a problem by applying an

inappropriate conceptual structure, this is done to apply their knowledge in solving a problem, even though the concepts used are incorrect, and 3) metacognitive blindness, described as metacognitive blindness failure occurring when students fail to recognize errors, for example, students who use inappropriate strategies or ignore calculation errors.

This research has the advantage that, if the analysis of metacognitive failures when using ChatGPT to solve mathematical problems is known, ChatGPT can be used properly and assist students' learning activities. ChatGPT can be an alternative tool for students in academic activities. Additionally, the research results can serve as a reference for the search for alternative tools to support effective learning and to expand knowledge about the role of technology, particularly artificial intelligence (AI), in student learning. Based on the above statement, the researcher feels the need to research metacognitive failures that may occur among students, especially first-year students, when using ChatGPT to solve mathematical problems. Thus, based on the background described above, the research objective is to analyze metacognitive failures among first-year students when using ChatGPT to solve mathematical problems.

Moreover, the emergence of AI tools such as ChatGPT has not only changed how students access information but also influenced their metacognitive regulation when solving problems (Baumanns & Rott, 2023). Students tend to rely on AI-generated solutions without critically analyzing their reasoning processes, which weakens self-regulated learning (Salsabila et al., 2024). From the perspective of Islamic education, thinking and reflection are central to learning: the Qur'an repeatedly invites believers to contemplate (*tafakkur*) on creation and to ponder (*tadabbur*) over its verses, thereby nurturing both intellectual and spiritual awareness (Zaini & Fauziah, 2024). These values call for learners to use technology responsibly and maintain a balance between rational inquiry and spiritual understanding. Therefore, this study not only aims to analyze the types of metacognitive failures students experience but also to interpret them through the spiritual-ethical lens of Islamic education, promoting intellectual integrity (*amanah ilmiyyah*) and self-reflection (*muhasabah*) in digital learning contexts.

Thinking is very important in mathematics. According to Ashar et al. (2021) thinking is a process that a person uses to remember and understand something. Meanwhile, Allsop (2019) state that thinking is a process carried out by students to obtain information, which is then used to find conclusions to solve problems related to geometry. This is in line with what was stated by that the thinking process of each student is different and not always the same between one student and another. Thus, in mathematics, thinking is a process of thinking with skills, freedom, and novelty in solving problems. According to Mawardi et al. (2023), in the 2013 curriculum revised in 2017, students are not only given formulas to solve problems, but they are also required to use their thinking skills to solve problems related to everyday life, one of which is geometry. In addition, in the learning process, for students to experience the thinking process,

the role of educators is needed to help develop students' thinking processes.

Geometry is an important branch of mathematics. In line with what was stated by Simarmata et al. (2024), geometry is a part of mathematics that is closely related to other parts of mathematics. According to Pramudita & Rosnawati (2019), studying geometry has several objectives, namely, to provide more comprehensive knowledge; to develop problem-solving skills; to play an important role in learning other concepts in mathematics; to be applicable in everyday life for many people; and to be an enjoyable subject. However, in reality, students have only known geometry as memorization and application to problems, but they do not know the overall meaning of geometry. In fact, students have been learning geometry since elementary school. Therefore, students should have broader opportunities in learning geometry. Thus, there needs to be an appropriate strategy in the geometry learning process so that students can be interested and contribute to geometry learning to achieve a level of geometric thinking in students (Schweizer et al., 2012).

The theory often used in geometry learning is Van Hiele's Theory. According to Arnal-Bailera & Manero (2024) Van Hiele's Theory of Geometric Thinking is a theory of student thinking in learning geometry, whereby students cannot skip higher levels without passing through lower levels. This theory also explains the development of students' thinking in learning geometry. Thus, in learning geometry, students experience the development of thinking skills through certain stages. Meanwhile, according to Hartono et al. (2025), Van Hiele states that in learning geometry, students go through five stages, each of which describes the thinking process of students in geometry material. This is in line with what Fitriyani et al. (2018) stated, that in Van Hiele's Theory, students will go through five stages in learning and understanding geometry. The five stages are level 0 (visualization), level 1 (analysis), level 2 (informal deduction), level 3 (deduction), and level 4 (rigor). Therefore, in order to move from one level of geometric thinking to the next, learning, especially geometry, needs to be adjusted between the learning experience and the students' level of thinking.

So far, there has been no research examining geometric thinking skills in flat-sided spatial figures from the perspective of Van Hiele's theory. Existing research have only discussed the difficulties students face in learning geometry. Based on the results of research by Aditya & Hiltrimartin (2024), it is stated that in geometry learning, junior high school students still memorize formulas but do not know the meaning of geometry and how to use it in solving problems because students do not understand the terms and symbols used in geometry problems. This shows that students have learned higher concepts but are not yet able to think maturely about basic things. In fact, junior high school students are expected to reach level 3 (deduction) of Van Hiele's Theory of Geometric Thinking. This is because, based on research conducted by Marchis (2012), if students do not reach level 3 (deduction) of Van Hiele's Theory of Geometric Thinking

in junior high school, they will have difficulty learning geometry in high school. In contrast, the results of research by Sudirman et al. (2024) state that some junior high school students operate at level 2 (informal deduction) of Van Hiele's geometric thinking theory.

Method

This study uses a qualitative approach to describe first-year students' metacognitive failures when using ChatGPT to solve mathematical problems. The type of research used is exploratory descriptive because the study aims to explore the cognitive processes of students, where students who are identified as experiencing metacognitive failures when using ChatGPT in solving mathematical problems are reviewed from three types of metacognitive failures, namely metacognitive mirage, metacognitive vandalism, and metacognitive blindness (Alifiani, 2022). This study was conducted in the Mathematics Education Study Program at the Islamic University of Malang, specifically among second-semester students in the 2023/2024 academic year. The sampling technique used in this study was purposive sampling. This non-probability sampling method selects participants based on specific characteristics aligned with the research objectives to address the study's problems. The sampling criteria in this study were second- semester students in the Mathematics Education Study Program in the 2023/2024 academic year who had taken the School Mathematics Material Analysis course. The research sample consisted of three students, selected based on the lecturer's recommendation and their final exam scores for the odd semester.

In this study, the instruments used were tests, the Metacognitive Awareness Inventory (MAI) questionnaire, and structured interviews. The test instrument consisted of three essay questions accompanied by scoring guidelines to facilitate assessment. Students used ChatGPT to help them complete the test questions. A Mathematics Education lecturer at the Islamic University of Malang validated the test instrument. The material tested was Two Variable Linear Equation Systems (SPLDV). After completing the questions, students were given the Metacognitive Awareness Inventory (MAI), a metacognitive questionnaire designed by Schraw & Dennison. The questionnaire used in this study was a closed-end one, with questions presented in detail and respondents only having to check the appropriate column. This questionnaire was given to determine whether students engaged in metacognition when completing the test questions.

After students complete the questionnaire, structured interviews were conducted, during which researchers identified the issues and questions to address the hypotheses formulated. Structured interviews were used to identify students' metacognitive failures when using ChatGPT to solve mathematical problems. Assad (2015) states that, although tests were administered to determine mathematics learning outcomes, little information was obtained about students' metacognitive involvement and the use of ChatGPT in solving mathematical problems.

Next, data validity testing was conducted to ensure the accuracy of the data obtained. Data validity is a concept that needs to be updated from the concepts of validity and reliability according to positivism, which are then adjusted to their own demands, paradigms, and criteria. The data validity exploration techniques used in this study were observer persistence and triangulation. Observer persistence is the implementation of research that is carried out more thoroughly and carefully to obtain information or data on the subject being studied. Finding characteristics and elements in conditions relevant to the issues being observed, and focusing on them, is the goal of the observer persistence technique.

Results and Discussion

Field research results show that some students experience metacognitive failure when using ChatGPT to solve math problems. The results of the field data analysis are as follows. The research subjects consisted of three students who had engaged in metacognition but were still unable to answer the test questions correctly. These three subjects were referred to as S1, S2, and S3.

It is known from the questionnaire and open interviews conducted that S1 has involved metacognitive abilities. In the initial step, when S1 reads the question, S1 engages in metacognition by rethinking his knowledge position, considering strategies for solving the problem, and reflecting on the relationship between his knowledge and the strategies he can use to solve it. S1 also did not find this stage difficult. S1 planned to solve the problem in question by working on it independently first, then, when they encountered difficulties, S1 would use ChatGPT's help. However, S1 forgot to write down the example used to continue working on the question. From the two equations known from the question, S1 used the first equation to create a new equation in the form of the value x. Then S1 substituted the value of x into the second equation from the question and obtained a quadratic equation. Next, S1 used the ABC formula for quadratic equations. The answer to S1 is provided in Figure 1.

Results should be clear and concise. The results should be supported by sufficient data. The following components should be covered in the discussion: How do your results relate to the original question or objectives outlined in the Introduction section (what/how)? Do you provide interpretation scientifically for each of your results or findings presented (why)? Are your results consistent with what other investigators have reported (what else)? Or are there any differences? Please highlight differences between your results or findings and the previous publications by other researchers.

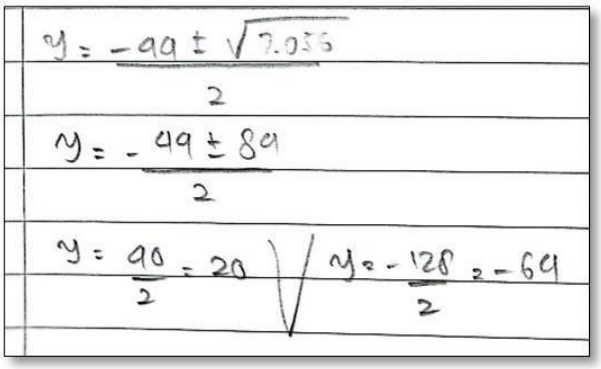

Figure 1. S1's answer

At the end of working out the ABC formula, S1 obtained the answer that *y* was negative, even though age cannot be negative. Here, S1 ignored this and immediately concluded that the ages of the two contestants were 20 and 64.

Furthermore, S2 involves metacognition in problem-solving, as revealed by questionnaire and interview results. Like S1, S2 involves metacognition in terms of rethinking their knowledge when faced with problems, the strategies they can use to solve problems, and the relationship between their knowledge and these strategies. S2's strategy was to first make assumptions based on what was known from the question, then work on it using substitution. However, during the process, S2 encountered difficulties and decided to use ChatGPT for help. From the answer, it was found that S2 used the first equation to derive a new equation in the form of *y*. Then, S2 substituted the value of y into the second equation from the question and obtained a quadratic equation. It turned out the quadratic equation had a negative result. In order for the result not to be negative, S2 multiplied the result by (-1). This was an incorrect step because when the values of *a*, *b*, and *c* from the quadratic equation were entered into the ABC quadratic equation formula, the resulting value was the root of a negative value, thus becoming an imaginary number. This error led S2 to the wrong answer, even though ChatGPT was used to assist in several stages of the process. From the interview, it was found that S2 realized that the root of a negative value is an imaginary number, which indicated that something was wrong. However, feeling tired, S2 ignored this and continued the problem-solving process. S2 also immediately wrote down the value of *x* and ignored the calculation error.

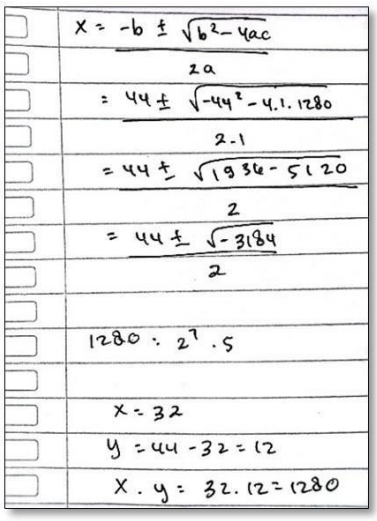

Figure 2. S2's answer

Meanwhile, S3 also involves metacognitive abilities, such as rethinking one's knowledge position when faced with a problem, problem-solving strategies, and the relationship between one's knowledge and the strategies used to solve problems. S3 planned to solve the problem by first understanding what was known and what was asked, then creating a new equation from the existing one to obtain the value of one of the variables to be substituted into another equation given in the question. In this case, the new equation obtained by S3 was y, which was then substituted into the second equation of the question: $x.y = 1280$. Here, S3 begins to realize that there is something wrong with the quadratic equation obtained, so he feels the need to multiply all sides by negative 1 (-1). However, this is not the right step because when the values of *a*, *b*, and *c* from the quadratic equation are entered into the ABC quadratic equation formula, the resulting value is the root of a negative value, which becomes an imaginary number. S3 actually abandoned the quadratic equation, which was the correct step. Next, S3 used ChatGPT to help solve the problem. Like S1 and S, S3 also used the quadratic equation ABC formula, but there was an error in writing down what ChatGPT stated.

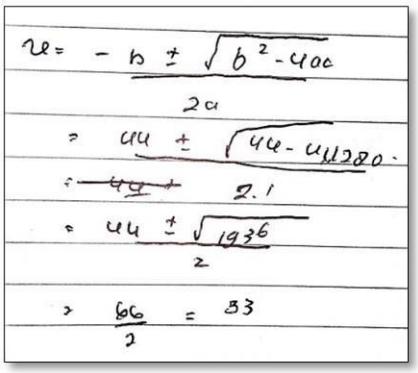

Figure 3. S3's answer

Here, the value of *b*, which should be squared, is not written correctly. Then, in the following line, S3 ignores the fact that the result of the square root calculation is negative, making it an imaginary number. From the interview, S3 admitted that he was tired when working on the problem, so he wrote it down carelessly and hurriedly and did not double-check his answers. S3 then continued working on the problem and found that the value of *x* obtained was 33.

According to Goos (2002), there are three types of MF, namely: (1) Metacognitive Blindness is a metacognitive failure when a person makes a mistake in the task completion process and does not recognize the “red flag." The red flags referred to here are processes that indicate the need for an individual to stop or recheck the problem-solving process in their metacognitive process. (2) Metacognitive Mirage is a metacognitive failure when an individual does not make a mistake but feels that there is a "red flag" when in fact there is none. (3) Metacognitive Vandalism is a metacognitive failure characterized by differences in the concept and context of the problem when responding to a "red flag". These three metacognitive failures can be described as follows. First, students were identified as experiencing metacognitive blindness when they failed to recognize errors in their problem-solving process. Second, students are identified as experiencing metacognitive vandalism when they change the problem by imposing an inappropriate conceptual structure to enable them to apply the knowledge they already have. Third, students are identified as experiencing metacognitive mirage when they feel a red flag and become doubtful when they encounter difficulties. However, the red flag they experience is a false alarm or mirage, which leads students to abandon helpful strategies.

Based on the indicators of metacognitive failure described above, the following conclusions can be drawn from this study's results. S1 experienced metacognitive failure —metacognitive blindness —because S1 failed to realize that the question contained an error. S2 experienced metacognitive vandalism: even though he realized the concept he was using was wrong, he continued to force himself to use it because he felt it was the only way he could. Meanwhile, S3 experienced a metacognitive mirage, feeling there was a red flag when in fact there was none. This caused S3 to abandon the proper strategy he had initially used and switch to another that yielded an incorrect answer.

The findings of this study are consistent with previous research by Alifiani (2022), who found that students often fail to monitor their cognitive strategies when dealing with ill-structured mathematical problems. In this research, all three subjects, S1, S2, and S3—demonstrated similar lapses but in different forms of metacognitive failure as categorized by Goos (2002). However, what differentiates this study is the integration of ChatGPT as an influencing variable. The use of ChatGPT provided a false sense of confidence for students, making them less reflective

in verifying the correctness of their answers, aligning with the phenomenon of "automation bias" described by Parasuraman & Riley (1997). This condition indicates that while AI tools can scaffold learning, they also risk diminishing metacognitive vigilance if used without proper regulation. Supporting this, a recent open-access study found that although learners perceived AI applications to be useful for metacognitive regulation, they emphasized the need for learner identity and active monitoring when using AI in learning (Chen et al., 2020) Thus, balancing technological benefits with reflective awareness is crucial in preventing the erosion of independent reasoning and sincere learning (Faradiba, 2019; Faradiba et al., 2025; Isminingsih et al., 2025; Maliana et al., 2025; Rohmah et al., 2025; Wardhana et al., 2025).

Conclusion

Based on research analyzing metacognitive failures among first-year students when using ChatGPT to solve mathematical problems, it can be concluded that metacognitive failures occur during this process. This can be proven by the results of data analysis of students' test answers. The metacognitive failures that occur are metacognitive blindness, metacognitive vandalism, and metacognitive mirage. To address this issue, it is necessary to make informed policy decisions on the use of AI in learning. Educators, especially university lecturers, should limit the use of AI in mathematics instruction, especially when students are working on math problems.

Therefore, it can be concluded that the presence of AI-based tools like ChatGPT has a dual impact: it facilitates access to problem-solving resources but can simultaneously induce metacognitive failures when students over-rely on automated reasoning. The three types of failures—metacognitive blindness, vandalism, and mirage—reflect not only cognitive imbalances but also ethical and spiritual challenges in learning. To address these, it is essential that educators foster *metacognitive awareness* and embed Islamic values such as *amanah ilmiyyah* and *tawakkul* in digital learning activities. This integration can nurture responsible technology use, encourage self-reflective thinking, and preserve the sincerity of learning as a form of *ibadah* (worship). Future research may extend this study by exploring metacognitive scaffolding models that combine AI assistance with reflective Islamic pedagogical principles.

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