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Student's Metacognition in Solving Mathematical Problem using Chat-GPT

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Abstract

This study aims to understand the metacognition processes of students in solving math problems with the assistance of Chat-GPT using a qualitative method and a case study approach. The research subjects are two eighth-grade students from a junior high school in Surabaya, selected through purposive sampling, with one subject representing successful students and the other representing unsuccessful students in the initial problem-solving test (PST). Data were collected through the initial PST, Chat-GPT-assisted PST, and interviews, then analyzed using metacognitive indicators: planning, monitoring, and evaluation. The successful subject actively engaged with Chat-GPT's answers, using metacognition processes to rethink their understanding, connect with prior knowledge, consider strategies, check steps, adjust errors, and verify solutions. Their errors stemmed from misunderstandings and incorrect information from Chat-GPT, but they adjusted and corrected their work upon prompt. In contrast, the unsuccessful subject only showed metacognitive engagement at the planning stage, struggling to understand the problem and prerequisite algebra material. They relied solely on Chat-GPT's answers without understanding or evaluating them, leading to ineffective problem-solving. The difference in metacognition processes between the subjects was attributed to cognitive factors, such as information received from Chat-GPT's answers, understanding of prerequisite material, and ability to comprehend the mathematical problem.

Keywords: chat-GPT, metacognition, mathematical problem, problem solving

Abstrak

Penelitian ini bertujuan untuk memahami proses metakognisi siswa dalam menyelesaikan masalah matematika dengan bantuan Chat-GPT menggunakan metode kualitatif dan pendekatan studi kasus. Subjek penelitian adalah dua siswa kelas VIII SMP di Surabaya yang dipilih melalui *purposive sampling*, dengan satu subjek mewakili siswa yang berhasil dan satu subjek mewakili siswa yang tidak berhasil dalam tes pemecahan masalah awal (PST). Data dikumpulkan melalui PST awal, PST berbantuan Chat-GPT, dan wawancara, kemudian dianalisis menggunakan indikator metakognisi: merencanakan, memantau, dan evaluasi. Subjek yang berhasil secara aktif terlibat dengan jawaban Chat-GPT, menggunakan proses metakognisi untuk memikirkan kembali pemahaman mereka, menghubungkan dengan pengetahuan sebelumnya, mempertimbangkan strategi, memeriksa langkah-langkah, menyesuaikan kesalahan, dan memverifikasi solusi. Kesalahan mereka berasal dari kesalahpahaman dan informasi yang salah dari Chat-GPT, tetapi mereka menyesuaikan dan memperbaiki pekerjaan mereka setelah diberi petunjuk. Sebaliknya, subjek yang tidak berhasil hanya menunjukkan keterlibatan metakognisi pada tahap perencanaan, kesulitan memahami masalah dan materi prasyarat aljabar. Mereka hanya mengandalkan jawaban dari Chat-GPT tanpa memahami atau mengevaluasinya, yang mengarah pada pemecahan masalah yang tidak efektif. Perbedaan dalam proses metakognisi antara subjek disebabkan oleh faktor kognitif, seperti informasi yang diterima dari jawaban Chat-GPT, pemahaman materi prasyarat, dan kemampuan memahami masalah matematika.

Kata kunci: chat-GPT, metakognisi, masalah matematika, pemecahan masalah

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Introduction

The aim of 21st-century education is not only to provide students with knowledge and information but also to prepare them to be independent and self-regulated, ensuring their academic and life success (Abdelrahman, 2020). The development of these skills can be honed through mathematics education. One of the objectives of teaching mathematics in schools is problem-solving. Through problem-solving, students can shape their personalities and develop the ability to regulate their thinking

processes effectively. Solving problems also involves finding ways and overcoming difficulties, not just arriving at the correct answer (Polya, 1957). Therefore, to successfully solve problems, students need to effectively manage their thinking, utilize acquired knowledge, and control and reflect on both the process and the outcomes of their thinking (Pramono, 2017).

Problems solved in mathematics often involve non-routine questions that students have not encountered through standard mathematical procedures or previously learned knowledge in the classroom (Siswono, 2008). Students struggling with problem-solving often do so because of their inability to connect what they have learned with how that knowledge can be applied (Maimunah et al., 2020). To solve mathematical problems effectively, several stages must be followed. The problem-solving stages proposed by Polya (1957) consist of four steps: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back. Polya's systematic stages facilitate students in problem-solving and help avoid errors in applying problem-solving strategies.

The level of a student's problem-solving ability is influenced by metacognition. Metacognition refers to an individual's knowledge about their own cognitive processes and products, or anything related to them (Flavell, 1979). Metacognition pertains to the understanding of knowledge, which can be reflected in the effective use of knowledge or in explicit explanations about it (Brown, 1978). In brief, metacognition is one's knowledge, awareness, and control over their thinking processes and outcomes (Rukhmana, 2021). Brown divided the components of metacognition into those related to the knowledge of cognition and the regulation of cognition. The regulation of cognitive activities includes three main processes: planning, monitoring, and evaluation. By utilizing those processes such as setting goals, monitoring progress, and evaluating outcomes, individuals can improve their ability to tackle complex problems efficiently.

According to Nasution et al. (2021), students with high metacognitive abilities can solve problems more effectively because they can regulate their existing knowledge. Conversely, students with low metacognitive abilities will struggle to solve problems (Cahdriyana, 2021). Research conducted by Puspitasari et al. (2023) indicated that low student metacognition is due to a lack of awareness in effectively managing their thinking to utilize their existing knowledge for problem-solving. Fitria's (2016) study on analyzing students' metacognitive difficulties in solving algebraic system of linear two variables problems revealed that students struggled to convert problems into mathematical form and lacked self-evaluation, leading to errors in operations and answers. Overconfident students tend to perform less self-evaluation and are less willing to make corrections in their problem-solving process.

Harks (2014) revealed that process-oriented feedback has a more positive impact on self-evaluation compared to grade-oriented feedback. Technology-based feedback enables students to correct their mistakes and helps them understand their own thinking processes, aligning with metacognition (Kuklick et al., 2023). One technology that serves as a feedback tool in 21st-century education is Chat-GPT. This technology is an artificial intelligence system that uses human-like responses to assist users in various situations (Setiawan & Luthfiyani, 2023). Mustafa's (2023) research on computational thinking for solving mathematical problems using Chat-GPT found that students actively learned and expressed their mathematical ideas through their thinking processes using the Chat-GPT program. Thus, Chat-GPT can provide feedback on the input given by students, thereby engaging them actively in constructing their knowledge.

Based on the issue of low metacognition in problem-solving abilities and the advantages of Chat-GPT in providing feedback on user input, along with its weakness where responses presented are not always correct, the researcher aims to investigate how students employ their metacognitive skills to plan, monitor, and evaluate problem-solving solutions generated by Chat-GPT. Previous relevant research has primarily focused on examining the relationship between metacognition and mathematical problem-solving, the metacognition processes of students using Chat-GPT, or mathematical problem-

solving itself. However, as a novelty in addition to the previously mentioned research, this study will specifically merge how students' metacognition processes interact with using Chat-GPT to solve mathematical problems.

Method

This study employs a qualitative research approach with a case study design The choice of this approach is based on the premise that students need to develop metacognition processes to understand and become aware of the strengths and weaknesses in planning, monitoring, and evaluating solutions provided by Chat-GPT. This research was conducted at junior high school in Surabaya, involving two eighth-grade students as subjects—one representing the successful category and the other representing the unsuccessful category in solving an initial problem-solving test. The categorization was based on scores from an algebraic operations problem-solving test, where successful subjects scored within the interval $67 < \text{score} \leq 100$, less successful within the interval $33 < \text{score} \leq 67$, and unsuccessful within the interval $0 \leq \text{score} \leq 33$. Both categories of subjects may exhibit different metacognition processes and difficulties in problem-solving.

The initial Problem-Solving Test (PST) consists of contextual problems involving middle school algebra operations, comprising 2 questions. Students will be given 30 minutes to complete the test. The initial PST is assessed based on Polya's problem-solving stages: understanding the problem, devising a plan, carrying out the plan, and looking back. Afterward, four subjects will take a second PST, consisting of 2 different contextual problems involving middle school algebra operations. The subjects will have 15 minutes to complete the test and will be asked to use Chat-GPT. Below are the test questions provided.

Andika ingin mengumpulkan uang setidaknya Rp 137.000 dalam seminggu untuk iuran liburan bersama temannya tetapi ia hanya memiliki uang Rp 25.000 di tabungan. Kebetulan, ayahnya menawarkan kesepakatan :

a. Akan membayarnya Rp 16.000 per jam jika ia belajar

b. Akan membayarnya Rp 40.000 jika membantu ibu membersihkan rumah.

Andika telah memutuskan untuk melakukannya kedua tugas itu. Berapa jumlah jam minimum yang dia perlukan untuk belajar agar dapat menutupi sisa kekurangan uangnya?

Andika wants to save at least Rp 137,000 in a week for a holiday contribution with his friends, but he only has Rp 25,000 in his savings. Fortunately, his father offers him a deal:

a. He will pay Andika Rp 16,000 per hour if he studies.

b. He will pay Andika Rp 40,000 if he helps his mother clean the house.

Andika has decided to do both tasks. What is the minimum number of hours he needs to study to cover the remaining amount he needs?

Figure 1. PST Using Chat-GPT Instument

The problem is used because it is a mathematical problem where the subjects must make assumptions, develop a calculation strategy, and solve it. Additionally, the problem was created by the researcher, ensuring that Chat-GPT has not encountered this specific input before. Therefore, there is a possibility of errors in Chat-GPT's responses, encouraging subjects to use their metacognition to

regulate and evaluate their thinking processes while using Chat-GPT. Following the test, individual interviews will be conducted to understand how the subjects' metacognition processes succeeded or failed in problem-solving based on the stages of metacognition: planning, monitoring, and evaluation.

The collected data is then analyzed using qualitative analysis techniques, which include data collection by searching for several reference articles, data reduction by selecting and eliminating irrelevant data from the interview results, data presentation in the form of test results and interviews, and drawing conclusions. From the interview sessions, the metacognition processes of each subject will be identified in both successful and unsuccessful categories. Below are the indicators for each metacognition stage to facilitate the analysis of the research results.

Table 1. Metacognition Indicators

Metacognition Stages	Indicators
Planning	a. Thinking about ways to find important information and the problem's objectives. b. Connecting the problem's relevance to prior knowledge and the information provided by Chat-GPT. c. Considering strategies to solve the problem by comparing personal knowledge with Chat-GPT's responses.
Monitoring	a. Comparing the solution steps with Chat-GPT's results to ensure the correctness of each step. b. Identifying necessary and unnecessary solution steps in Chat-GPT's responses. c. Adjusting the solution steps when encountering difficulties or errors in Chat-GPT's output.
Evaluation	a. Verifying the correctness of the solutions generated by Chat-GPT. b. Assessing the relevance of Chat-GPT's solutions to the problem's objectives.

Result and Discussion

Based on the results of the initial problem-solving test, subject STA obtained the highest score and subject KN obtained the lowest score. Subsequently, each subject was assigned a code in the table below to facilitate data analysis.

Table 2. Subject of Research

Subject	Initial PST Scores	Category	Code
STA	93	Successful	SB
KN	9	Unsuccessful	ST

Metacognitive Process of Successful Subjects (SB) in Solving Mathematical Problems Using Chat-GPT

There are the solution results on the answer sheet and the Chat-GPT results for SB.

1. **Mengidentifikasi informasi penting:**
   - Total uang yang ingin dikumpulkan Andika: Rp 137.000
   - Uang yang sudah dimiliki Andika: Rp 25.000
   - Kekurangan uang yang perlu dikumpulkan: $137.000 - 25.000 = 112.000$
   - Ayahnya akan membayarnya Rp 16.000 per jam jika ia belajar.
   - Ayahnya akan membayarnya Rp 40.000 jika membantu membersihkan rumah.
2. **Menyusun persamaan:**
   Misalkan x adalah jumlah jam yang Andika perlukan untuk belajar dan y adalah jumlah kali Andika membantu membersihkan rumah.
   - Uang yang didapat dari belajar: $16.000x$
   - Uang yang didapat dari membantu membersihkan rumah: $40.000y$

Total uang yang didapat harus memenuhi kekurangan uang:

$$16.000x + 40.000y = 112.000$$

3. **Mencari solusi dengan minimal jam belajar** (x):
   Untuk menentukan jumlah jam minimum yang Andika perlukan untuk belajar agar menutupi kekurangan uangnya, kita asumsikan $y = 0$ (artinya Andika tidak membantu membersihkan rumah).

   Maka persamaan menjadi:

$$16.000x = 112.000$$

   Untuk mencari x:

$$x = \frac{112.000}{16.000} = 7$$

4. **Kesimpulan:**
   Jika Andika hanya mengandalkan belajar untuk mengumpulkan uang, dia perlu belajar selama 7 jam untuk menutupi sisa kekurangan uangnya sebesar Rp 112.000.

2. Ditetahui. Uang yang harus dikumpulkan minimal 137.000
Andika hanya memiliki 25.000
Ayah Andika akan memberinya uang jika:
1. Ia belajar, 16.000/jam
2. Ia membantu bersih², 40.000/setiap membersihkan

Ditanya - Berapa jam minimal yang harus dia habiskan untuk belajar agar sisa uang yang dibutuhkan tercapai?

Jawab: kekurangan uang Andika: 137.000 - 25.000 = 112.000

112.000 = 16.000 x

7 = x

Maka, Andika harus belajar minimal 7 jam untuk menutupi sisa uang yang ia butuhkan untuk liburan

Figure 2. Problem Solving Result of SB

SB completed the problem in less than 15 minutes of the allotted time. Based on these results, it is evident that the problem-solving generated by Chat-GPT and SB's answers were also inaccurate. After conducting the interview, during the planning stage, SB tried to reconsider their understanding of the problem by reading the question multiple times, but they were not thorough in reading the question. There was a keyword indicating that Andika decided to do both tasks, which SB did not understand well. The lack of metacognition in reconsidering their understanding of the problem led to errors in comprehension, as shown in the following conversation below.

PW-01 : "Did you read carefully that "Andika decided to do both tasks"?

SB-01 : "Oh yes, I didn't fully understand the meaning of that sentence. It means Andika also helps his mother."

PW-02 : "Did you have difficulty understanding the problem?"

SB-02 : "Not really. I thought the question only asked about study hours. So, I ignored the sentence about Andika doing both tasks."

PW-03 : "Can you explain how you formulated your solution strategy using your understanding and the information from Chat-GPT?"

SB-03 : "The question asks for the minimum study hours needed to meet the shortfall in money. So, I assumed x to be the study hours. I calculated the shortfall in money, then divided it by Rp 16,000 since he earns Rp 16,000 per hour of study."

PW-04 : "Are you confident that this strategy that generated by Chat-GPT could solve the problem?"

SB-04 : "Yes, using that formula I could find x, which is the minimum study hours."

SB connected their knowledge of algebra and used Chat-GPT to formulate a strategy or steps for problem-solving. However, they did not adequately consider the correctness of the solution strategy because they believed that the strategy they had formulated and the one generated by Chat-GPT were correct, due to their insufficient understanding of the problem. From the monitoring stage, SB attempted to verify the accuracy of each calculation step by calculating independently on the scratch paper provided and comparing it with the Chat-GPT's answer. SB did not simply copy Chat-GPT's answer but selectively wrote down only the necessary calculation steps. However, due to a misunderstanding, SB did not notice the errors in Chat-GPT's solution. As a result, they did not adjust the steps, missing the step of subtracting the shortfall with the money earned from helping their mother. However, after the researcher questioned their understanding again, SB realized the errors in the steps taken and corrected them properly that can be shown in the conversation below.

PW-05 : "If Andika decides to do both tasks, will the problem-solving steps remain the same?"

SB-05 : "I think it will be different. It means the Rp 112,000 should be reduced by Rp 40,000 because Andika earns Rp 40,000 from helping his mother."

PW-06 : "How do you ensure the correctness of Chat-GPT's solution?"

SB-06 : "I calculated it myself and confirmed that the result is 7."

PW-07 : "How did you calculate it?"

SB-07 : "I substituted x with 7, and the result is Rp 112,000."

From the evaluation stage based on the above dialogue, SB was confident that the solution generated by Chat-GPT was correct because they calculated it themselves by substituting x with 7, following the steps provided by Chat-GPT, and obtained Rp 112,000, which is the amount Andika needs to earn.

Metacognitive Process of Unsuccessful Subjects (ST) in Solving Mathematical Problems Using Chat-GPT

There are tthe solution results on the answer sheet and the Chat-GPT results for ST.

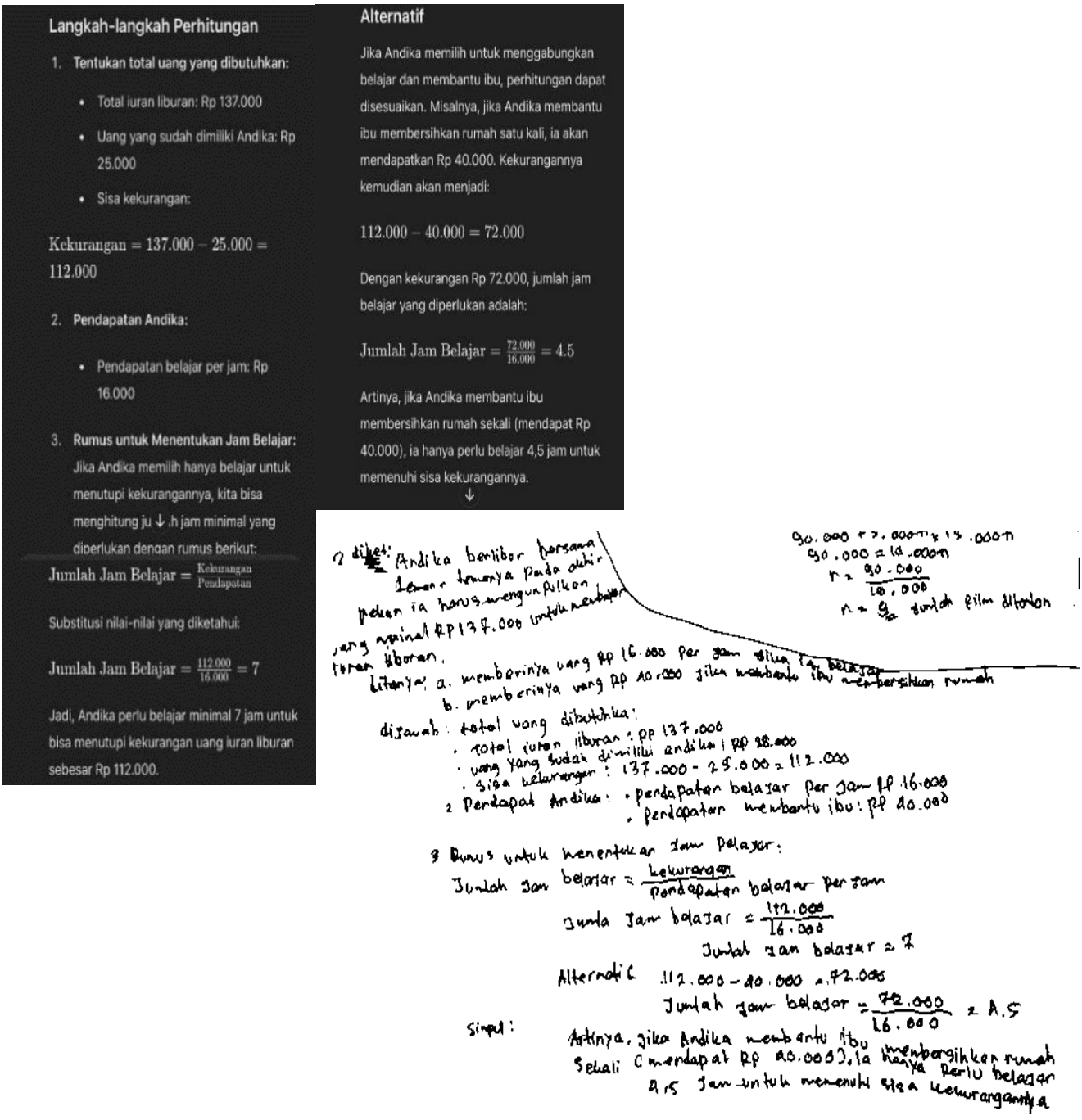

Figure 3. Problem Solving Result of ST

ST took longer than SB to complete the problem, requiring more than 15 minutes. From the results above, it can be seen that ST copied the entire answer from Chat-GPT. Chat-GPT provided two solutions: the first one was incorrect, while the second one was correct. ST wrote down both solutions because they did not consider that one of the answers was incorrect. In the planning stage, ST tried to reconsider their understanding of the problem by repeatedly reviewing Chat-GPT's solution. ST mentioned that they had previously studied the prerequisite material for solving the given problem, which is algebra, but due to their limited understanding of algebra, they did not critically evaluate the strategy provided by Chat-GPT. They admitted to feeling confused, leading them to decide to write down all the information given by Chat-GPT. In addition, they were unable to evaluate the correctness of the two strategies provided by Chat-GPT due to their lack of understanding of the given mathematical problem. The planning stage process is illustrated in the following interview results.

PW-01 : *"How are you confident that you understand the problem?"*

ST-01 : *"I tried to understand the Chat-GPT results. That's why it took me a long time."*

PW-02 : *"With your understanding of the problem and your knowledge of algebra, do you think Chat-GPT's solution plan is correct?"*

ST-02 : *"I don't really understand the algebra part. I only understood the part about subtracting 137,000 by 25,000."*

PW-03 : *"And after that?"*

ST-03 : *"After that, I got confused. So, I looked at Chat-GPT's answer."*

In terms of monitoring, ST did not verify the correctness of Chat-GPT's steps because they did not understand the problem-solving approach provided by Chat-GPT. Therefore, they simply copied the answer without identifying the necessary steps in the solution and did not consider that one of the two solutions could be less accurate. They admitted to having difficulty understanding the problem but did not attempt to seek clarification from Chat-GPT that can be shown in the conversation below.

The research results showed that SB did not solely rely on Chat-GPT's answers, whereas ST depended entirely on Chat-GPT's solutions. In the planning stage, SB was able to reconsider their understanding of the problem by reading the question and Chat-GPT's information, and by connecting their understanding with their knowledge of algebra. Additionally, SB considered Chat-GPT's strategy based on their understanding and knowledge. Meanwhile, ST also read Chat-GPT's information repeatedly but still did not understand. They admitted to having a limited understanding of the prerequisite material, which is algebra. Therefore, they did not evaluate the correctness of the two strategies provided by Chat-GPT. In the monitoring stage, SB verified Chat-GPT's steps by calculating them independently on scratch paper. They also filtered out unnecessary steps from Chat-GPT's solution. SB's errors were due to their confidence in Chat-GPT's answers and their initial understanding, which prevented them from identifying errors in Chat-GPT's steps. This aligns with Wulandari (2019), who stated that students with high mathematical ability use their metacognition to solve problems, even if they make minor mistakes when answering questions. Meanwhile, ST did not verify Chat-GPT's steps because they did not understand the problem well and lacked the prerequisite algebra knowledge to solve it. Therefore, ST simply copied Chat-GPT's steps. According to Rahayu (2019), when solving problems, if students are unable to master the previous stages, they will have difficulty proceeding to the next stages.

In the evaluation stage, SB assessed the correctness and relevance of the solutions to the problem's objectives with mathematical calculations. SB's misunderstanding led to incorrect solutions. This was also supported by errors in Chat-GPT's information or answers. This is consistent with Suryana (2022), who stated that in information management, there is an interaction between internal conditions (cognition) and external conditions (learning resources) that leads to learning outcomes. Meanwhile, ST did not know how to verify the correctness and relevance of the two solutions generated by Chat-GPT mathematically. This is consistent with the research findings of Rizqiani (2019), which showed that students with low abilities demonstrate an inability to test solutions to ensure the correctness of the

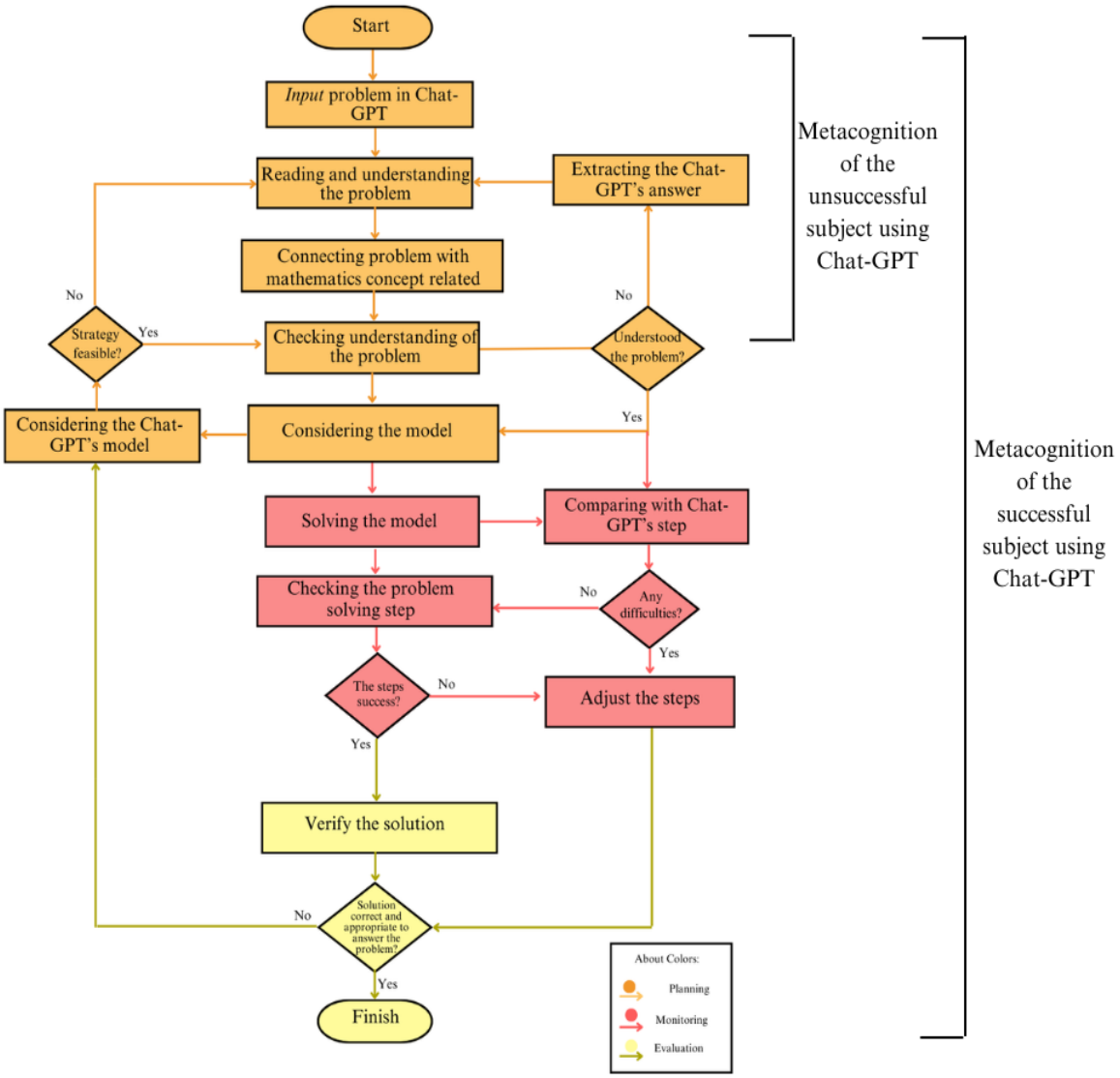

Figure 4. Flowchart of The Metacognition Process

The flowchart above illustrates the metacognitive process of both subjects. The unsuccessful subject demonstrates their metacognitive process in solving problems using Chat-GPT only during the planning stage. Meanwhile, the successful subject is able to demonstrate the metacognitive process comprehensively at each stage.

Conclusion

Based on the discussion presented, it can be concluded that the difference between the successful subject and the unsuccessful one was apparent from their ability to use their metacognitive thinking process. The successful subject used Chat-GPT's answers only as a consideration and further incorporated a thorough metacognitive process of rethinking, connecting, checking, identifying, adjusting, and verifying to obtain a correct solution. The errors found in this subject's work were merely due to misunderstandings of the received information generated by Chat-GPT where they were able to further verify the solution and develop the correct answer. Meanwhile, the unsuccessful subject merely copied Chat-GPT's answers where their metacognitive process was only demonstrated at the planning stage, rethinking their understanding of the problem. They failed to understand the problem due to their inability to grasp the given mathematical problem, even with assistance from Chat-GPT. Additionally, they admitted not understanding the prerequisite material needed to solve the problem, namely algebra. As a result, they relied solely on Chat-GPT's answers without thoroughly understanding the problem or considering the accuracy of Chat-GPT's responses. The difference in metacognition processes between the subjects was attributed to cognitive factors, such as information received from Chat-GPT's answers, understanding of prerequisite material, and ability to comprehend the mathematical problem.

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