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Revealing the dominant metacognitive activities of high school students in solving central tendency and dispersion problems based on gender

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Abstract

Research on the relationship between gender and metacognition in mathematical problem-solving has yielded inconsistent findings. Some studies suggest that gender influences metacognitive activities, while others report no significant differences. This study seeks to explore metacognitive activities during each stage of statistical problem-solving among two 12th-grade students with contrasting gender expressions: a feminine-expressing female and a masculine-expressing male. The instruments utilized in this research include the Bem Sex Role Inventory (BSRI) gender questionnaire, a mathematical ability test, a statistical problem-solving task, and an interview guide. Data collection was conducted in two phases: the BSRI questionnaire and mathematical ability test were used to classify participants, followed by problem-solving tasks and semi-structured interviews to capture their metacognitive processes. Employing a descriptive exploratory design with a qualitative approach, the study applied thematic analysis to organize and interpret data from task performance and interview transcripts. These findings were further synthesized into hierarchical diagrams to illustrate the dominance of metacognitive components at different problem-solving stages. Results indicate that the feminine-expressing female predominantly utilized metacognitive knowledge, specifically declarative knowledge, during the problem-understanding phase. In contrast, the masculine-expressing male demonstrated more reliance on metacognitive regulation, particularly in planning and monitoring, during the problem-implementation stage. These findings underscore the importance of developing inclusive curricula and differentiated teaching strategies to enhance metacognitive skills across diverse student populations.

Keywords: Case Study, Dominant Metacognitive, Gender, Statistical Problem

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Metacognition, defined as the ability to reflect on and regulate one's cognitive processes, has long been recognized as a critical factor in fostering effective learning and academic achievement (Kuhn, 2022). As a multifaceted construct, metacognition has garnered substantial attention within the field of psychology. Central to its definition, metacognition encompasses both the awareness and understanding of one's cognitive functions, as well as the regulation of these processes (Flavell, 1979; Schraw, 2009). The concept is commonly divided into two primary components: metacognitive knowledge and metacognitive regulation (Moshman, 2018; Schraw & Moshman, 1995). Metacognitive knowledge refers to individuals' understanding of their own cognitive strengths and limitations, their preferred learning strategies, and their insights into the nature of learning and problem-solving (Moshman, 2018). This awareness enables individuals to tailor their learning approaches and select the most effective strategies for particular tasks. In contrast, metacognitive regulation involves the active monitoring and management of cognitive processes, such as planning, self-monitoring, and evaluating one's progress during problem-solving (Schwartz et al., 2013; Tuncer & Kaysi, 2013).

Metacognition has long been regarded as a critical factor in successful problem-solving. It has been identified as a predictor of problem-solving ability (Jamil et al., 2023). A growing body of research underscores the importance of metacognitive activities in enhancing problem-solving capabilities. One such activity, metacognition, is a significant variable influencing mathematical achievement (Wutsqa et al., 2024). Furthermore, engaging in metacognitive practices fosters a deeper understanding of the problem, facilitates the selection of appropriate strategies, and enables ongoing monitoring and adjustment of one's approach throughout the problem-solving process. Additionally, metacognition involves evaluating both one's thought processes and the outcomes of problem-solving (Nath, 2016). Metacognitive skills also play a pivotal role in regulating the problem-solving process by overseeing calculations, ensuring the accuracy of solutions, and organizing the overall approach (Güner & Erbay, 2021). Thus, students who employ metacognitive strategies tend to demonstrate greater success in problem-solving, as they are able to identify the nature of the problem, select suitable strategies, and monitor the effectiveness of their chosen approaches (Safari & Meskini, 2015). Recent studies have confirmed a significant positive correlation between metacognitive awareness and problem-solving proficiency, emphasizing the importance of metacognitive awareness for effective problem-solving (Utami et al., 2023). Moreover, metacognition is essential for the development of critical thinking, as it entails awareness of one's cognitive processes and the deliberate decision-making involved in problem-solving (Rivas et al., 2022). Collectively, these findings consistently highlight the indispensable role of metacognition in mathematical problem-solving.

Research has indicated that gender differences influence the utilization of metacognitive strategies (Zulfikar & Masni, 2021), which are closely linked to cognitive processes and metacognition as crucial determinants of academic performance and learning outcomes (Yin et al., 2023). Scholars have extensively explored gender differences in cognitive processes, examining how male and female students may employ distinct strategies and exhibit varying abilities. However, the relationship between gender, cognitive processes, and academic achievement is complex and multifaceted (Agger & Meece, 2015). While some studies suggest that females demonstrate superior intellectual performance across a range of subjects, others yield contradictory findings, particularly within the context of STEM education. The generalizability of these results is often constrained by the specific cultural and demographic contexts in which the studies were conducted (Liliana & Lavinia, 2011). These inconsistencies underscore the necessity for further research to better understand the intricate interplay between gender, cognition, and academic success.

When examining metacognitive success through the lens of gender differences in students, a variety of patterns emerge. For example, some studies suggest that gender influences metacognition in problem-solving processes (Widiyasari, 2023; Yurt, 2022), while others report no significant effect of gender on this variable (Doz et al., 2023). One study found that female students exhibit higher levels of metacognitive knowledge and extrinsic academic motivation compared to their male counterparts (Abdelrahman, 2020). Additionally, research examining metacognitive skills across different educational levels has indicated that females tend to demonstrate superior metacognitive skills in comparison to males (Jenkins, 2018). Further studies on gender differences in metacognitive skills have consistently shown that girls are generally more proficient in metacognitive processes, particularly in problem-solving and planning (Yurt, 2022). However, other research found no significant gender differences in metacognitive skills (Doz et al., 2023; Garzón et al., 2020). Additionally, some studies have suggested that while emotions can interfere with cognitive processes, they do not appear to be influenced by gender differences (Gur et al., 2023). These findings imply that both genders may employ similar strategies equally, with problem-solving being the most frequently utilized approach. This inconsistency warrants further investigation. Therefore, it is crucial to identify the specific metacognitive activities at each stage of mathematical problem-solving to better understand how gender influences metacognitive processes across the different layers of problem-solving.

The significance of identifying specific metacognitive activities at each stage of problem-solving is underscored by Blummer and Kenton (2014), who found that distinct metacognitive activities occur at each phase of problem-solving. Consequently, the framework for this study, presented in Table 1, is grounded in the concept of metacognition, which encompasses the components of "metacognitive knowledge" and "metacognitive regulation" (Flavell, 1979; Moshman, 2018). Metacognitive knowledge pertains to an individual's awareness of themselves as cognitive processors, the various approaches available for learning and problem-solving, and the demands associated with specific learning tasks (Flavell, 2000). This knowledge is composed of three primary components: declarative knowledge, procedural knowledge, and conditional knowledge (Moshman, 2018). Declarative knowledge refers to an individual's awareness of their cognitive strengths and weaknesses in learning and processing information. Procedural knowledge pertains to the understanding of task types and the cognitive demands necessary to complete them. Conditional knowledge involves knowledge of the strategies that can be applied to successfully complete tasks, including when and why to utilize specific strategies in problem-solving (Aliu et al., 2021).

Table 1. Metacognitive indicators

Subcomponent	Activity	Code
Declarative Knowledge	Knowing consciously about one's own abilities, including memory, weaknesses, and strengths.	DK
Procedural Knowledge	Knowing about how to apply steps in doing something	PK
Conditional Knowledge	Knowing about why and when to use the correct information and procedures in doing something	CK
Planning	Developing a plan to solve the problem	P
Monitoring	Being directly aware of their understanding and cognitive performance in solving problems	M
Evaluating	Evaluating and assessing the control process and outcome of his/her thinking in solving the problem	E

Metacognitive regulation, on the other hand, involves the activities that individuals engage in to facilitate learning and memory (Schraw, 2009). It refers to the regulation of cognition and learning experiences through activities that help individuals control and optimize their learning process (Ackerman, 2014). Metacognitive regulation includes three essential processes: planning, which involves setting goals and determining strategies for learning and problem-solving; monitoring, which refers to continuous awareness of one's understanding and task performance; and evaluation, which entails assessing the outcomes and effectiveness of one's learning efforts (Moshman, 2018).

Both metacognitive knowledge and metacognitive regulation are crucial for effective learning and problem-solving, as they enable individuals to identify their cognitive strengths and weaknesses, understand the demands of tasks, and adapt their approach accordingly. These components also facilitate the selection of optimal strategies for specific tasks, as well as the continuous monitoring and evaluation of learning and progress. The interaction between self-awareness, self-monitoring, and self-regulation (Abdelrahman, 2020) enhances individuals' understanding of their cognitive processes, empowering them to effectively manage their cognitive resources in pursuit of learning goals (Chowdhury, 2021). Furthermore, metacognition allows learners to gain insight into their learning processes, identify which strategies are most effective, and adjust their approach based on their strengths and weaknesses (Al-Sinani et al., 2022). Metacognitive skills enable students to set clear goals, plan their approach, and monitor their progress, thereby fostering more effective learning outcomes. In addition, metacognition plays a critical role in regulating various aspects of learning, including time management, motivation, and emotional control, all of which are essential for academic success (Stanton et al., 2021).

These subcomponents are integrated into each stage of problem-solving, from understanding the problem and planning the solution to implementing the plan and reviewing the outcomes (Polya, 1973). This framework serves as a foundation for examining and analyzing high school students' metacognitive activities in solving statistical problems, with a particular emphasis on gender differences. The primary components of this framework include Flavell and Schraw's model of metacognition, as revised by Moshman, along with related theories that elucidate the role of metacognition in learning and problem-solving, as shown in Figure 1.

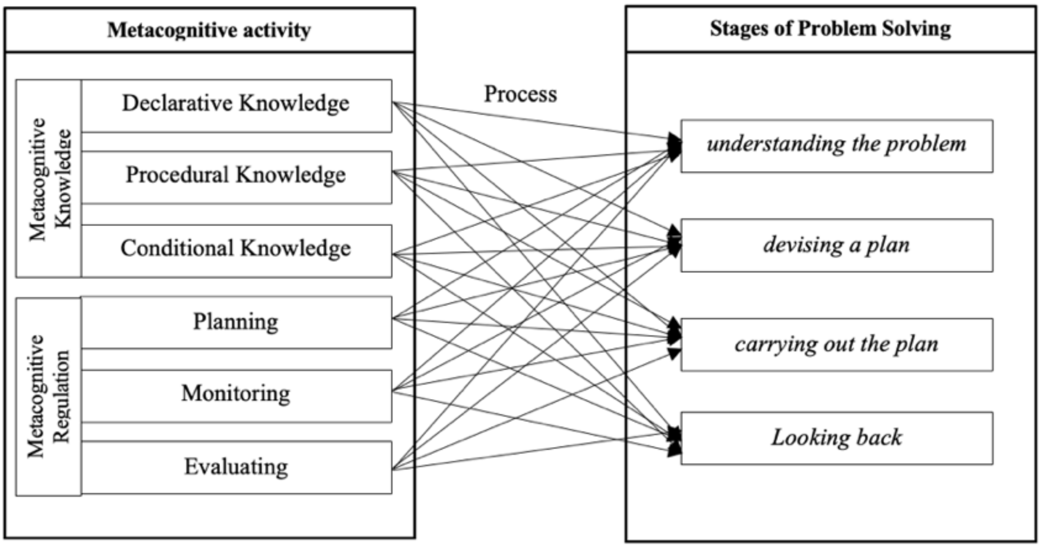

Figure 1. Conceptual framework

Understanding gender beliefs and stereotypes is crucial for developing strategies that promote gender equality, particularly in educational contexts. Recognizing the factors that contribute to the gender gap in learning can lead to the creation of more effective strategies to improve academic outcomes for both males and females (Van Hek et al., 2016). These strategies may include, but are not limited to, addressing stereotypes, promoting gender equality, and developing tailored teaching methodologies. Therefore, investigating gender differences in academic performance, particularly in STEM subjects, can help identify the underlying factors contributing to this gap and inform strategies to mitigate them, ultimately advancing gender equality (Wrigley-Asante et al., 2023).

One of the subjects within STEM is Statistics, where statistical problem-solving is a critical skill that students must master. However, many students face significant challenges in this area, as it demands a strong grasp of mathematical concepts, the ability to critically analyze data, identify patterns, and draw meaningful conclusions. Teaching and learning statistics is inherently complex, regardless of the teaching methodology employed (Anasagasti et al., 2023). A key challenge in statistical problem-solving is the substantial variation in data that can obscure underlying patterns and relationships (Azmay et al., 2023). Students must cultivate the ability to recognize and account for variation, utilizing techniques such as summarization and visualization to uncover significant insights. Nevertheless, students can overcome these challenges by employing effective metacognitive strategies, thereby developing a deeper understanding of statistical reasoning and thinking (Yuniawatika, 2018). Metacognition enables students to critically analyze problems, facilitating the selection of appropriate strategies for resolution (Izzati & Mahmudi, 2018). Research has shown that higher levels of metacognitive awareness are positively correlated with improved performance in statistical tasks (Izzati & Mahmudi, 2018).

Finally, this study aims to identify the distinct stages of problem-solving and compare the dominant metacognitive activities of feminine-expressing female students and masculine-expressing male students in solving statistical problems. The findings of this study are expected to provide valuable insights for educators, informing the integration of learning strategies and the development of distinct approaches for male and female students based on their differing metacognitive strategies, particularly in the context of statistics. With the implementation of well-structured learning strategies, it is anticipated that the challenges students face in statistical problem-solving can be more effectively addressed.

METHODS

Research Design

To examine the problem-solving processes of the participants and identify the predominant metacognitive activities exhibited by feminine-expressing female students and masculine-expressing male students, an exploratory case study employing a qualitative approach was conducted. This methodology enables a comprehensive investigation of a particular case, facilitating a deeper understanding of a complex issue (Carter, 2020; Cresswell, 2013). Such an approach was deemed appropriate, as it allows for a detailed description and analysis of metacognitive activities during problem-solving tasks. Additionally, this design provides the opportunity to uncover recurring themes in metacognitive processes among participants when addressing statistical problems (Vaismoradi et al., 2016).

Research Instrument

The instruments employed in this study included the Bem Sex Role Inventory (BSRI) gender questionnaire (Bem, 1974), a mathematics ability test, a statistical problem-solving task (Henra et al., 2024), and interview guidelines. The BSRI gender questionnaire comprises sixty items with seven response options, categorizing participants into four gender expression groups: feminine, masculine, androgynous, and undifferentiated. The mathematics ability test was adapted from the national examination and consisted of eight questions, with two questions representing each of the following domains: number, geometry, statistics, and algebra. The statistical problem-solving task was designed around a single non-routine word problem, containing three questions related to central tendency and dispersion. The validity of this task was ensured through expert validation. Reliability testing was not conducted, as the instrument was not intended to assess metacognitive or problem-solving abilities, but rather to gather information on students' metacognitive activities during the problem-solving process. The interview guidelines were based on the Metacognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994). The interview consisted of twenty-three questions: eight related to metacognitive knowledge and fifteen to metacognitive regulation. These questions were structured to facilitate the exploration of students' responses.

Participants

A statistical problem-solving task was administered to two 12th-grade students from a public senior high school in South Sulawesi, Indonesia. Participant selection began with the administration of the BSRI Gender Questionnaire (Bem, 1974) and a mathematics ability test to 30 students who had studied statistics in the semester prior to the study. The BSRI Gender Questionnaire identified 16 feminine-expressing female students and 14 masculine-expressing male students, which were considered representative of the gender diversity within the school. The mathematics ability test was used to assess students' mathematical proficiency. Scores were categorized as high (≥ 80), moderate (60 ≤ score < 80), and low (< 60) according to Ratumanan and Laurens (2011). The results indicated that the majority of students (23 out of 30) fell into the moderate ability category, and these students were selected as potential participants. Two students with moderate mathematical ability were chosen: one feminine-expressing female and one masculine-expressing male. Although the limited number of participants may restrict the generalizability of the findings, it was believed that the selection process would facilitate a more in-depth analysis of metacognitive activities.

Data Collection

A statistical problem-solving task (Henra et al., 2024), as shown in Figure 2, was developed by adapting statistical problem contexts from the 12th-grade high school syllabus. This task was employed as an instrument to explore students' metacognitive activities through in-depth interviews. The materials used aligned with the content of the statistical problem-solving task developed for this study. The researchers oversaw the entire process, from administering the problem-solving task to conducting the in-depth interviews, ensuring that the students' problem-solving activities were solely based on their independent thinking, without interference from external factors or tools. Evidence of the students' metacognitive activities during problem solving was gathered from their written responses and from their verbal and non-verbal communications, which were recorded during video interviews with the researchers.

> A coin arrangement competition was held for students during the Nusantara Indah High School anniversary celebration. The competition was attended by six students: Radit, Gita, Adi, Nuning, Linda, and Sambo. The first group comprised male participants, namely Radit, Adi, and Sambo. Radit managed to arrange coins as high as 70 cm, Adi as high as 60 cm, and Sambo as high as 20 cm. The second group consisted of female participants, namely Gita, Nuning, and Linda. Gita managed to arrange the coins as high as x cm, Nuning as high as 30 cm, and Linda as high as 40 cm. If the results of the coin arrangement height of the first and second group participants are combined into one data so that the mean and median values are the same, then;
> a. Find the value of x if the height of Gita's coin is greater than that of Sambo's!
> b. Find the variance of the coin arrangement height data if Gita's height is more significant than Radit's height!
> c. Find the standard deviation of the coin arrangement height data if Gita's height is more significant than Radit's height!

Figure 2. The task for this study

Both participants were initially given time to read and comprehend the statistical problem-solving task without attempting to solve it immediately. This understanding phase lasted approximately 5 to 10 minutes. Subsequently, students were interviewed about their cognitive processes during the understanding and planning stages of the task. The semi-structured interview questions were designed and adapted from the MAI based on the previously outlined framework. Once the researcher had gathered sufficient and relevant data, both participants were asked to proceed with solving the problem according to their understanding and plan. This phase lasted between 20 to 30 minutes. After the students completed the task, follow-up interviews were conducted to explore the students' activities during the execution and reflection stages of the problem-solving process.

Data Analysis

The participants' processes during each task and interview were recorded using an audio-visual recorder. The students' responses during the interviews, based on the statistical problem-solving task, were transcribed verbatim. These transcriptions, along with the students' written answers from the problem-solving task, were analyzed to identify evidence of their metacognitive activity processes. Thematic analysis was employed to examine the written responses, students' activities during problem-solving, and the interview transcripts (Miles et al., 2018). The metacognitive activities of the feminine-expressing female student and masculine-expressing male student were categorized using the framework outlined in Table 1. It is important to note that the analysis focused on the students' reflections during task-based interviews regarding their thinking processes while solving statistical problems, rather than on the accuracy of their answers to the statistical problem-solving task. This approach aligns with the perspective of Kane et al. (2014), who emphasized that articulating and reflecting on the outcomes of students' thinking is crucial for understanding and developing their metacognitive activities.

The coding of metacognitive activities was based on specific indicators (see Table 1). For example, in the declarative knowledge subcomponent, responses were coded as DK when students explained the content of the material, the difficulty level of the problem, and their strengths and weaknesses in solving the problem. In the procedural knowledge subcomponent, responses were coded as PK when students described the strategy, method, formula, or steps they intended to use in solving the problem. In the conditional knowledge subcomponent, responses were coded as CK when students explained the rationale for choosing specific strategies, methods, formulas, or steps in solving the problem. In the planning subcomponent, responses were coded as P when students described how they would identify known and unknown information, the relationship between the current problem and previously solved problems, or the strategies, methods, formulas, or steps they would employ. In the monitoring subcomponent, responses were coded as M when students expressed confidence in the correctness of their chosen strategy, method, formula, or steps, checked the validity of their chosen approach, viewed the problem from a different perspective, or compared their planned approach with its implementation. Finally, in the evaluation subcomponent, responses were coded as E when students solved problems using different methods, assessed the applicability of their chosen strategies, methods, formulas, or steps to other problems, evaluated their thinking and working process, or evaluated the achievement of their goals.

RESULTS AND DISCUSSION

This section presents the participants' responses to the statistical problem-solving task, along with the transcriptions of the dialogues between the researcher and the participants during the interview sessions. The students' metacognitive activities at each stage of statistical problem-solving are analyzed and interpreted based on their responses, written solutions, and interview transcripts. To maintain anonymity, pseudonyms are used for each participant. "Subject-1" refers to a female-identifying student, while "Subject-2" denotes a male-identifying student.

Understanding the Problem

The analysis of metacognitive activities revealed notable differences between Subject-1 (a female-identifying student) and Subject-2 (a male-identifying student) in various dimensions of metacognitive knowledge and regulation when addressing statistical problems. With regard to declarative knowledge, both participants demonstrated awareness of their memory capacity, as well as their strengths and weaknesses. Additionally, both students were able to grasp the material and assess the difficulty level of the problem. This indicates that both subjects utilized metacognitive knowledge during the problem-understanding phase, as reflected by the indicators of declarative knowledge. This is illustrated by the following excerpt from the interview:

Researcher : After attempting to understand the question, what do you think the question is about?
Subject-1 : Statistics, sir.
Subject-2 : It is about statistics, sir.
Researcher : Could you explain how difficult you find the material and what content you have studied previously?
Subject-1 : Actually, I've studied this before, sir, but I find it somewhat challenging. It includes calculations such as the median, mean, mode, variance, standard deviation, and quartiles.
Subject-2 : We covered this last semester, sir. I find it difficult because some data values are unknown. For this material, the first step is to find the mean, then the median, variance, and standard deviation.

However, with regard to procedural knowledge, Subject-1 exhibited a broader awareness. Subject-1 demonstrated not only an understanding of procedural steps—such as the inability to calculate variance without complete data, the significance of data quantity, and the correct use of formula symbols—but also a more comprehensive grasp of various procedures. In contrast, Subject-2 focused primarily on the data distribution and the process of calculating the mean. This indicates that Subject-1 possessed a more detailed procedural understanding compared to Subject-2. The following excerpt from the interview illustrates this:

Researcher : Why did you say that the height of the coin is important information?
Subject-1 : … because it is only possible to calculate the variance if the data is complete, sir.
Researcher : Why do you think the shape of the data is important?
Subject-2 : … because, to answer this question, the frequency must be known first in order to calculate the mean, sir.

In terms of conditional knowledge, Subject-1 also demonstrated a deeper understanding. Subject-1 was able to recognize when to seek clarification or request opinions on the application of specific formulas, whereas Subject-2 only recognized the need to use the formula for the mean. This suggests that Subject-1 exhibited a stronger awareness of the context and situations influencing the selection of appropriate procedures compared to Subject-2. This is further exemplified in the following interview excerpt:

Researcher : How do you address the weaknesses you mentioned earlier?
Subject-1 : First, I ask for opinions from my friends or seek help. For example, if I'm unsure or confused about a formula—such as the mean, median, variance, or standard deviation—I discuss it with my peers to ensure I complete the task efficiently. This way, the cognitive load of solving the problem is reduced.
Researcher : Why did you choose to use the mean formula?
Subject-2 : … to find the average value, sir.

In the planning phase, Subject-1 again displayed a more comprehensive strategy than Subject-2. Subject-1 identified various critical elements required for solving the problem, including planning for grouped data, recognizing known and unknown information, and developing strategies for understanding the problem. Conversely, Subject-2 acknowledged important data, such as group data, known and unknown information, and the requirement that the mean and median must be identical. This indicates that Subject-1 exhibited a more structured and detailed approach to planning than Subject-2. This is illustrated in the following interview excerpt:

Researcher : What do you consider the most important information about this problem?
Subject-1 : The data on the height of the coins in the competition, sir, as well as the requirements for the height of the coins in each question and the condition that the mean and median must be the same.
Subject-2 : The shape of the data, sir, the number of data points for each group, and the requirement that the mean and median must be the same.

Finally, in the monitoring phase, Subject-1 recognized the importance of finding the value of x as a key piece of data in the second group, while Subject-2 identified only one of six missing data points from the female group. This suggests that both subjects applied metacognitive regulation based on the monitoring indicators, but Subject-1 demonstrated more targeted and specific monitoring. This is evident in the following interview excerpt:

Researcher : How is the value of x important in this problem?
Subject-1 : Because the x value is part of the height of Gita's coin in the second group, sir.
Subject-2 : Because it is one of six unknown data points, sir.

Devising A Plan

The results of the metacognitive analysis revealed differences between Subject-1 (a female-identifying student) and Subject-2 (a male-identifying student) across various aspects of metacognitive knowledge and regulation during the development of their statistical problem-solving plans. In the aspect of conditional knowledge, Subject-1 demonstrated an understanding of the essential components of the problem, such as the importance of the mean and median formulas, and when to apply the formulas for the mean, median, standard deviation, and variance. In contrast, Subject-2 identified the key elements of the problem, including the need to complete the data on the height of the coins participating in the competition, the requirements for the mean and median values, and the appropriate formulas for calculating variance and standard deviation. This suggests that while both subjects utilized conditional knowledge in developing their problem-solving plans, Subject-1 placed a broader focus on the application of statistical formulas in general, whereas Subject-2 focused more on the specific context of the problem. This distinction is illustrated in the following interview excerpt:

Researcher : Do you recognize the key components of this problem, and how did you identify them as important?
Subject-1 : I think the most important components are the mean and median, as these are the main points of the question. The second part, concerning variance, cannot be answered unless the mean and median are known first.
Subject-2 : Yes, sir, the unknown height of Gita's coin is important because knowing the height will complete the data, making it easier to calculate the mean, median, variance, and standard deviation.

In terms of planning, Subject-1 demonstrated a more comprehensive awareness. Subject-1 recognized that she had encountered similar problems before and understood the ultimate goal of solving the problem in accordance with the question. She also devised a strategy: to directly apply the mean and median formulas based on the key information from the question. Subject-2 also acknowledged familiarity with similar problems, although less complex than the current one, and recognized the goal of answering all questions in the statistical problem-solving task. In addition, Subject-2 identified several other goals and developed a more intricate strategy, which included noting down the known and unknown information, determining the value of *x*, and applying the mean and variance formulas based on key data. This suggests that Subject-2 had a more detailed and structured plan. This is evident in the following interview excerpt:

Researcher : How will you solve this problem?
Subject-1 : ... I will first collect and organize the data. Then, I will address each part of the question, A, B, and C. The problem also asks for variance and standard deviation, which I recall studying in the first semester. My teacher taught us how to calculate variance and standard deviation as well, sir.
Subject-2 : ... I will first list what is known and what needs to be found, sir. Then, I will determine the value of x. I've learned the formulas for mean and median before, but this one seems more complicated, sir ...

In the monitoring phase, Subject-1 demonstrated an awareness of how to set goals based on the three questions regarding the value of *x*, variance, and standard deviation. Subject-2 also exhibited monitoring awareness, focusing on completing the coin height data before addressing the other questions. Both subjects employed metacognitive regulation in monitoring their problem-solving process, although their approaches differed in terms of focus and strategy. This is reflected in the following interview transcript:

Researcher : How did you determine the goals you wanted to achieve?
Subject-1 : ...I think the problem must have an answer, so there are three specific questions in this task, and my goal is to determine the answer to each of them, sir.
Subject-2 : ... I think I should start by determining the value of Gita's coin height first, sir.

Carrying Out the Plan

The metacognitive analysis results revealed distinct profiles between the two subjects at this stage. In the aspect of declarative knowledge, Subject-1 (a feminine-expressing female student) identified several obstacles during the statistical problem-solving process, including difficulties in determining the variance value, the ineffectiveness of guessing the value of *x*, and the absence of alternative methods for solving for *x*. In contrast, Subject-2 (a masculine-expressing male student) recognized the challenge of manually performing the root operation in the standard deviation formula. Both subjects applied declarative knowledge to acknowledge and understand the constraints they encountered, but their focus differed: Subject-1 emphasized the limitations of the guessing process, whereas Subject-2 concentrated on the challenges related to manual calculations. This distinction is illustrated in the following interview excerpt:

Researcher : What obstacles did you face?
Subject-1 : ... I forgot the variance formula, sir, so I attempted to guess based on the data pattern to ensure that the mean and median were the same. However, I think this method is less effective ...
Subject-2 : ... I was confused by the calculation of the standard deviation value, sir, so I just guessed and estimated the value ...

In terms of procedural knowledge, Subject-1 demonstrated awareness of the essential steps required to calculate the value of x, as well as the mean, median, and variance. She understood the relevant formulas and the necessary data processing techniques, such as sorting and calculating based on the known and unknown information (see Figure 3). On the other hand, Subject-2 recognized more advanced procedural strategies, such as using the lumping method to balance the total data across groups, and applying the formulas for variance and standard deviation (see Figure 4). This indicates that while both subjects understood the procedural steps required to solve the problem, Subject-1 focused more on the fundamental procedures, while Subject-2 employed more complex strategies, such as modeling techniques. This difference is evident in the following interview excerpt:

Researcher : How did you find the value of 80?
Subject-1 : ... I inferred it from the known information, sir. It was stated that the height of Gita's coin must be higher than Sambo's coin, which is 20, so Gita's coin must be higher than 20. Then, Gita's coin must also be taller than Radit's, whose coin is 70, so Gita's coin must be above 70. Using this method, I found it useful to check each piece of data one by one according to the initial plan, although this method is time-consuming and could potentially be simplified with a formula ...
Researcher : How did you guess the number for the x value?
Subject-1 : ... It has to be above 20, so it could be 40 or 50. But, since the next clue specifies it must be higher than Radit's coin, which is 70, I eliminated 30, 40, and 50, as they are too low. So, I tried 80 first. If 80 doesn't work, I would try 90, sir.
Researcher : How did you find the mean value of 50?
Subject-2 : ... For the male group, I added all the data and then divided it by 3 to get the mean of 50. For the female group, I only knew two data points, so I added them up and assumed the total would be 150, in order to make the mean and median the same. Then, I used this total to solve for x (where 70x = 150), and I obtained x = 80. By dividing 150 by 3, I arrived at the mean of 50. This method worked, but I guessed that the value of x might not be correct, so I proceeded

with this calculation ...

Researcher : How did you guess the number for the x value?

Subject-2 : ... Before I settled on the total of 150, I tried values for x such as 30, 40, and 70, but the mean was not consistent. So, I revised the total to 150 to ensure consistency with the mean ...

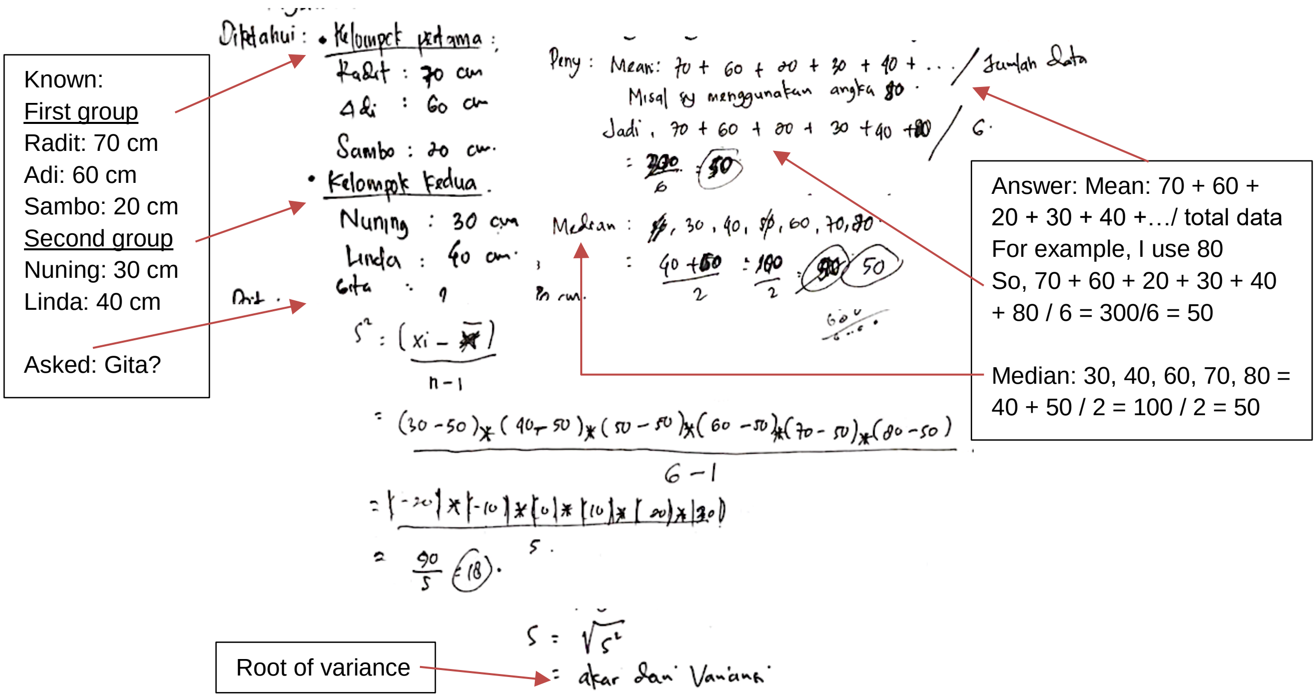

Figure 3. Results of solving statistical problems by Subject-1

In terms of conditional knowledge, Subject-1 recognized that in order to calculate the standard deviation and variance, the value of *x* must first be determined. In contrast, Subject-2 understood that by combining the data from both groups and taking the middle value, the median could be made consistent between the groups, which led to the same mean and median values (see Figure 4). Both subjects demonstrated an understanding of when and why certain information and procedures should be applied. However, Subject-1 placed more emphasis on the relationship between the value of *x*, variance, and standard deviation, while Subject-2 focused more on data combination as a means to achieve specific goals. This difference is illustrated in the following interview excerpts:

Researcher : Why did you not answer the standard deviation?

Subject-1 : ... There is no result, sir, if the root value is 18, which is impossible to answer if the variance is unknown ...

Researcher : How can the median value between the groups be the same?

Subject-2 : ... I use the median of single data, sir. I combine and sort each group, then take the middle value. For example, the male group fits in at 60, and the female group at 40 ...

In the planning aspect, Subject-1 exhibited a clear understanding of both the known and unknown information, recognizing the importance of writing down the information as a guide for problem-solving (see Figure 3). She also had a clear strategy to find the mean, median, variance, and standard deviation.

On the other hand, Subject-2 also demonstrated awareness of the known and unknown information, as well as the strategy to find the mean and variance. However, Subject-2 placed more focus on memorization techniques and the process of guessing the value of *x* (see Figure 4). This demonstrates that both subjects engaged in effective planning, though Subject-1 adopted a more systematic approach by writing down the steps and using data patterns for guessing, while Subject-2 relied more on memorizing formulas and adjusting values. This distinction is evident in the following interview excerpts:

Researcher : How did you calculate the value?

Subject-1 : ... I guess the answer, sir. For the value of x, I add up the data and divide by the number of data points. The median is obtained by first sorting the data from lowest to highest and identifying the middle value. For example, if the data points are 40 and 60, I add them up to get 100, then divide by 2. For variance, I subtract the mean from each data point, square the result, sum them up, and divide by the number of data points. The standard deviation is simply the square root of the variance, sir.

Subject-2 : ... Before I tried to estimate with 150, I tested values for x such as 30, 40, and 70, but the mean was still inconsistent. So, I adjusted the total to 150 to achieve a consistent mean. For the median, I used the median of single data, sorted each group, and then took the middle value and divided by two. For the mean, I subtracted the variance from each data point, squared the results, summed them up, and then divided by 6. The standard deviation is the square root of the variance.

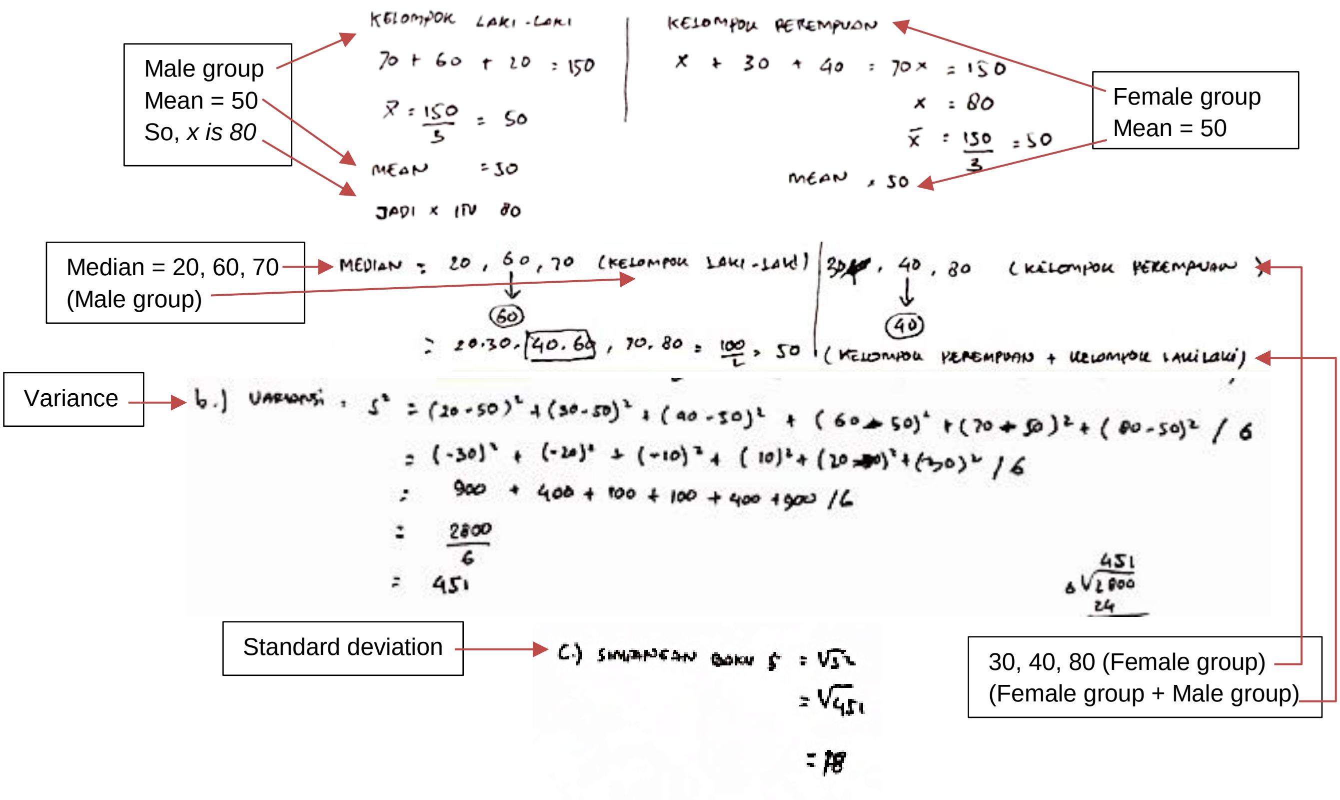

Figure 4. Results of solving statistical problems by Subject-2

In the monitoring aspect, Subject-1 expressed confidence in the accuracy of the values she found, explaining that she had double-checked the calculations according to the formula and the conditions outlined in the statistical problem-solving task. She also recognized the importance of following the instructions regarding the coin heights in the problem. Similarly, Subject-2 showed confidence in the values of x, mean, variance, and standard deviation that he obtained, noting that he used trial and error to ensure they met the problem's requirements. Both subjects exhibited effective monitoring by rechecking each value based on the specifications of the question. This is evident in the following interview excerpts:

Researcher : Are you sure the mean value equal to 50 is correct?
Subject-1 : ... Yes, Sir, I am sure. I rechecked it earlier, and it matches the mean formula...
Researcher : Are you sure the value of x = 80 is correct?
Subject-2 : Yes, it is correct, Sir, because it is 20 cm higher than the height of Sambo's coin. The mean and median are also the same.

In the evaluation aspect, Subject-1 realized that the standard deviation value could not be determined because the variance value still required correction, meaning that the goal of part C of the question had not been met. In contrast, Subject-2 recognized that his initial method of finding x using the group data table was incorrect, so he switched to using the single data method. He also realized that x = 80 met the conditions of the problem, ensuring that both the mean and median were the same, and that the height of Gita's coin arrangement was greater than Sambo's. Both subjects used evaluation to reflect on and conclude their problem-solving process. However, Subject-1 focused more on the accuracy of the variance and standard deviation, while Subject-2 concentrated on the effectiveness of the method and its alignment with the problem's requirements. This distinction is illustrated in the following excerpts:

Researcher : Why don't you try to work on the standard deviation? Can this be the answer to the variance of 18?
Subject-1 : ... Yes, sir, but I tried to calculate it, and there is no result if the root value is 18.
Researcher : How did you become convinced that the mean and median are important?
Subject-2 : ... I reread the information earlier when doing parts A, B, and C, Sir. A is different from B and C, as B and C share the condition that they are higher than Radit's coin, whereas A does not. So, one of them, between B and C, cannot be answered.

Looking Back

The findings from the metacognitive analysis revealed distinct differences between the two study subjects in the process of reflecting on their solutions to statistical problems. In the aspect of declarative knowledge, Subject-1 (a female student with feminine self-expression) recognized that the method she employed was not the correct formula and felt that a more appropriate approach could have been used. Conversely, Subject-2 (a male student with masculine self-expression) identified his weakness in manually performing the root operation within the standard deviation formula. Both subjects utilized declarative knowledge to assess their weaknesses, with Subject-1 focusing more on the accuracy of the method used, while Subject-2 emphasized specific difficulties in manual calculation. This contrast is evident in the following interview excerpts:

Researcher : Is there another approach you tried?
Subject-1 : That was all I could think of, sir, because I didn't believe that was the right formula.

Researcher : Why did you focus so much on rechecking the x-value?
Subject-2 : I was uncertain about my answer, especially the standard deviation. I was concerned that I might miscalculate because I tend to make errors when calculating manually.

In the aspect of monitoring, Subject-1 acknowledged that she rechecked her answer to ensure it aligned with the required data for the coin height and reviewed her written work for accuracy. Similarly, Subject-2 recognized the need to reread and verify the answer with respect to the x-value and standard deviation to avoid potential errors. Both subjects demonstrated effective monitoring; however, Subject-1 emphasized verifying the data requirements, whereas Subject-2 concentrated on checking for writing errors. The following interview segment further illustrates this distinction:

Researcher : How do you double-check your answers?
Subject-1 : I double-check to ensure the data is correct and that there are no discrepancies in my writing; I often find that the values I write above and below are inconsistent.
Subject-2 : I just make sure that the answers are accurate, especially in case there are any writing errors. Earlier, I tried using the group table because I was stuck, then I switched to the single data method to match the mean value.

Regarding the evaluation aspect, Subject-1 reflected on her performance, acknowledging that she could have done better, as she was unable to solve all the questions correctly and had relied on guessing in some instances. Furthermore, she realized that the value of x should correspond to both the mean and median values, and she assessed that her work process followed the procedure, despite not achieving the desired outcome. In contrast, Subject-2 recognized that he had used a different method to equalize the mean and median values. He expressed doubt about some of his answers, particularly the standard deviation value, but still believed that his work process was sound and in line with the procedure. Subject-2 also reflected that he had successfully achieved his goal, as he managed to solve all the questions in parts A, B, and C. This is evident in the following interview excerpts:

Researcher : In terms of percentage, how well did you perform on this question?
Subject-1 : I would estimate it's not 50%, because out of three questions, I'm only confident about two answers.
Subject-2 : I would say about 90%, since I was able to solve all the questions, although I'm still uncertain about some of the answers, particularly the standard deviation.

These results suggest that both feminine-expressing female students and masculine-expressing male students engage in metacognitive knowledge and regulation activities to facilitate finding the correct solution when solving statistical problems. Metacognitive knowledge and regulation play an integral role at each stage of the problem-solving process, enhancing students' ability to plan, monitor, and evaluate their approach (Santiago et al., 2024). These findings are consistent with the work of Moshman (2020), which emphasizes the importance of supporting students in managing and directing their problem-solving process, as it influences every stage from understanding the problem to evaluating the solution (Hancock & Karakok, 2021). Throughout all stages of problem solving—comprehending the problem, planning, executing the plan, and reflecting on the results—metacognitive knowledge and regulation assist students in task analysis, planning, monitoring, checking, and reflecting, ultimately contributing to improved problem-solving outcomes in mathematics (Noor, 2022).

Dominant Metacognitive Activity in Problem-Solving

Feminine-Expressing Female Student (Subject-1)

The hierarchical diagram mapping presented in Figure 5 illustrates that Subject-1's metacognitive activities during the solution of statistical problems exhibited varying degrees of dominance at different stages. At the problem comprehension stage, metacognitive knowledge played a central role, with Declarative Knowledge (DK) being the predominant subcomponent, surpassing Procedural Knowledge (PK) and Conditional Knowledge (CK). Subject-1 demonstrated an awareness of her strengths and weaknesses, utilizing this information to guide her approach. Metacognitive regulation was also significant at this stage, particularly in the Planning (P) subcomponent, which overshadowed monitoring. This indicates that Subject-1 was able to plan her cognitive process effectively and select appropriate strategies when attempting to understand the statistical problems.

Figure 5. Profile of subject-1's dominant metacognitive activity in solving statistical problems

In the planning phase, metacognitive regulation became more dominant than metacognitive knowledge. Within metacognitive regulation, P subcomponent took precedence over Monitoring (M). Subject-1 exhibited strong control over her cognitive processes, effectively planning her approach and selecting the most suitable strategies. During this stage, metacognitive knowledge primarily involved CK, indicating that Subject-1 was aware of when to apply specific knowledge to construct an effective plan for solving the statistical problem.

At the stage of implementing the plan, metacognitive regulation again took precedence, particularly in M subcomponent, followed by planning and evaluation. Subject-1 displayed an ability to manage her cognitive processes, remain aware of her performance and understanding, and adjust her thinking as needed. Metacognitive knowledge continued to play a significant role, with PK dominating, followed by DK and CK. This suggests that Subject-1 was not only familiar with the correct procedures but also knew when to apply specific knowledge during the execution of her solution plan.

At the stage of looking back on the results of the solution, metacognitive regulation again predominated, particularly in the Evaluation (E) subcomponent, which was more prominent than M. Subject-1 demonstrated the ability to critically assess her cognitive outcomes, reflecting on her performance and understanding. The metacognitive knowledge that emerged at this stage was primarily DK, indicating that Subject-1 was conscious of her cognitive abilities, including her memory, strengths, and weaknesses.

Subject-1's metacognitive activities were most prominent during the execution of the solution plan and the comprehension of statistical problems. In the implementation phase, metacognitive regulation, especially M, P, and E, was dominant. During the comprehension stage, metacognitive knowledge—mainly DK, PK, and CK—was more prominent. This reflects Subject-1’s strong control over her cognitive processes, as she was able to apply the appropriate knowledge and strategies to effectively solve the statistical problems.

Masculine-Expressing Male Student (Subject-2)

The hierarchical diagram presented in Figure 6 reveals that Subject-2's metacognitive activities in solving statistical problems exhibited distinct patterns of dominance across various stages. During the problem comprehension phase, metacognitive knowledge predominated, particularly DK. Subject-2 demonstrated awareness of his abilities, including memory, strengths, and weaknesses, and was capable of planning appropriate strategies. Metacognitive regulation also played an essential role at this stage, with P emerging as more dominant than M. This suggests that Subject-2 was able to effectively plan his cognitive approach and select suitable strategies when understanding the statistical problems.

In the planning phase, metacognitive regulation continued to be more dominant, particularly in the P subcomponent. Metacognitive knowledge was also present, with DK, PK, and CK contributing to his understanding. This indicates that Subject-2 was able to exercise strong control over his cognitive processes, carefully plan the steps to be taken, and reflect on his abilities and understanding of the task.

At the stage of executing the solution plan, metacognitive regulation remained dominant, particularly in M, followed by P and E. Subject-2 exhibited strong control over his cognitive processes, maintaining awareness of his performance and understanding, and adjusting his thinking as necessary. Metacognitive knowledge, particularly PK, continued to be important, followed by DK and CK. This suggests that Subject-2 was familiar with the correct procedures and knew when to apply specific knowledge during the implementation of the solution.

Upon reflecting on the results, metacognitive regulation again dominated, particularly in the E subcomponent, followed by M. The metacognitive knowledge observed at this stage was exclusively DK, indicating that Subject-2 was aware of his cognitive abilities, including memory, strengths, and weaknesses, and was able to evaluate and assess the outcomes of his thinking. Through this reflection, Subject-2 gained insights into his performance and understanding of the solution.

Overall, Subject-2's metacognitive activity was most prominent during the implementation of the solution plan and the understanding of statistical problems. In the execution phase, metacognitive regulation, particularly M, P, and E, played a dominant role. During the problem comprehension phase, metacognitive knowledge—comprising DK, PK, and CK—was most prominent. These findings suggest that Subject-2 demonstrated strong control over his cognitive processes and was able to apply the appropriate knowledge and strategies to solve statistical problems effectively.

Figure 6. Profile of Subject-2's dominant metacognitive activity in solving statistical problems

Furthermore. the findings of this study also highlight distinct differences in the dominance of metacognitive components at various stages of statistical problem-solving between the two students. In general, both subjects, despite differences in gender, demonstrated that metacognitive regulation played a crucial role during the implementation of the solution plan and the evaluation of the solution results (Jaleel & Premachandran, 2016). On the other hand, metacognitive knowledge was more prominent during the stages of understanding the problem and formulating the solution plan. These results align with the study by Blummer and Kenton (2014), which asserts that metacognitive activities serve as input layers at every stage of problem-solving.

The significance of these findings lies in the deeper understanding they offer regarding how students with differing gender characteristics and expressions utilize their metacognitive abilities in the context of statistical problem-solving. Subject-1, a female student exhibiting feminine expression, predominantly relied on declarative knowledge at the problem comprehension stage. This reliance on declarative knowledge is closely associated with feminine expression, which often emphasizes emotional and affective dimensions (Boyapati & Khan, 2023). As a result, Subject-1 tended to be more introspective, particularly in terms of understanding her strengths and weaknesses while solving problems. This observation is consistent with previous research (Doulik et al., 2015), which suggests that declarative knowledge provides a solid foundation for planning and comprehending the problem before transitioning into the regulation stage (Saks et al., 2021). Furthermore, this finding illustrates that Subject-1 possessed a high level of self-awareness regarding the information at her disposal and was able to strategically employ it during the problem-solving process.

On the other hand, Subject-2, a male student exhibiting masculine expression, demonstrated a similar metacognitive pattern but with differences in the proportions of metacognitive knowledge use and metacognitive regulation. In the case of Subject-2, metacognitive regulation was more dominant during the stages of developing and executing the solution plan, with monitoring and evaluation emerging as the primary subcomponents. This aligns with findings from a previous study (Severiens & Ten Dam, 2012), which suggests that students with this profile tend to exhibit greater regulation of their cognitive processes throughout problem-solving (Maharani et al., 2019). Related research indicates that while females generally show more complexity and structure in their evaluation activities, males tend to display greater complexity and structure in their awareness-related activities (Ramlah et al., 2024).

These findings underscore that, despite differences in how the two subjects utilize their metacognitive abilities, both exhibit a strategic approach that aligns with the specific demands of each problem-solving stage (Saryanto et al., 2021). Moreover, these results emphasize the importance of cultivating metacognitive regulation skills, such as planning, monitoring, and evaluation, across all students. These skills not only support statistical problem-solving but are also transferable to other learning contexts and subject areas. Additionally, a strong foundation in metacognitive knowledge, particularly declarative, procedural, and conditional knowledge, should be instilled early to enhance students' confidence and learning efficiency (Stanton et al., 2021).

The implications of this study's findings on metacognitive activities in statistical problem-solving are significant for educational practice. It is essential for curricula to be adapted to accommodate the metacognitive needs of students with diverse gender characteristics, ensuring appropriate support for the development of metacognitive skills (Auhadeeva et al., 2015). Developing metacognitive regulation skills, such as planning, monitoring, and evaluation, is crucial for all students as it contributes to success in various learning contexts (Abdellah, 2015; Taylor, 1983). In parallel, fostering strong metacognitive knowledge—comprising declarative, procedural, and conditional knowledge—should be a priority in early education to bolster students' confidence and learning efficiency (Stel et al., 2010). Regardless of gender, students who effectively regulate their cognition are more likely to succeed in solving complex mathematical and academic problems (Barokah et al., 2020).

Finally, the challenge for educators is to implement diverse teaching strategies that cater to the differences in metacognitive knowledge use and regulation between female and male students. This will help maximize their potential in understanding and solving problems. A personalized learning approach that recognizes students' self-awareness of their abilities, strengths, and weaknesses is vital for enhancing learning effectiveness and problem-solving capacity. One of the strategies that educators can adopt to stimulate metacognitive activity is to ask students directly about their cognitive processes—what they are doing, why they are doing it, and how they plan to proceed. This method helps separate cognitive activities (what) from metacognitive activities (why or how), fostering reflective thinking and strengthening metacognitive abilities.

CONCLUSION

This study has demonstrated that female students expressing femininity and male students expressing masculinity employ metacognitive strategies in a deliberate manner when solving statistical problems. The feminine-expressing female student predominantly utilized metacognitive knowledge, particularly declarative knowledge, during the problem comprehension phase. Conversely, the masculine-expressing male student relied more heavily on metacognitive regulation, focusing on planning and monitoring throughout the implementation phase. Both participants exhibited strong cognitive control, albeit through distinct approaches.

The feminine-expressing female student showed considerable potential in balancing both knowledge and metacognitive regulation in statistical problem-solving. However, indecision and excessive caution, influenced by emotional awareness, appeared to negatively affect performance. This highlights the necessity of incorporating emotion and affect regulation into educational programs that address not only cognitive skills but also emotional management. The masculine-expressing male student displayed high confidence in problem-solving but often overlooked the critical evaluation of their thought processes. This suggests the importance of exercises that encourage reflection and evaluation of cognitive strategies.

The findings of this study have successfully mapped the metacognitive profiles of students in the context of statistical problem-solving, identifying the dominant metacognitive activities engaged by students at each problem-solving stage. However, the research is limited in that it has not differentiated between positive and negative metacognitive activities, due to the lack of specific observation indicators that could distinguish these characteristics. Furthermore, the scope of the material was confined to descriptive statistics, specifically central tendency and dispersion.

To enhance the generalizability of these results, future studies should expand the sample size and diversity of participants. Additionally, future research could explore the impact of personalized teaching methods on the development and application of metacognitive skills. Further investigations into metacognitive activities in the domain of inferential statistics are also warranted to assess whether these findings hold across more advanced areas of statistics. Finally, longitudinal studies are recommended to examine the development of metacognitive skills, such as metacognitive knowledge and regulation, over time, as well as the effectiveness of interventions, such as reflective learning, in fostering this development.

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Declarations

Author Contribution : KH: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Visualization, Writing - original draft, Writing - review & editing.

IKB: Supervision and Validation.

I: Supervision and Validation.

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