Unlocking Metacognitive Potential: A Journey Through the Minds of Androgynous High School Students in Statistical Problem Solving

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Abstract
Metacognitive activities are essential to academic achievement and cognitive development during adolescence. This study aims to investigate the metacognitive activities of androgynous students in solving statistics problems. To deeply uncover the complex interaction between androgynous identity and metacognitive strategies, a qualitative approach with semi-structured in-depth interviews based on a statistics problem-solving task adopted from the Metacognition Awareness Inventory was used. The participants were three high school students with moderate mathematical ability, consisting of one androgynous student and two non-androgynous students as a comparison. The findings of this study revealed a spectrum of metacognitive strategies used by androgynous students. Androgynous students demonstrated cognitive flexibility, smoothly transitioning between analytical and intuitive approaches based on problem characteristics. All participants were empowered with metacognitive knowledge and metacognitive regulation to monitor and adapt cognitive processes during problem-solving, but androgynous students had greater knowledge control. In addition, androgynous students demonstrated goal-oriented planning in breaking down the complexity of statistical problems and aligning metacognitive strategies with goals. This study underscores the influence of gender identity on metacognition. Androgynous students, free from traditional gender-related cognitive stereotypes, utilize a broader range of metacognitive approaches than non-androgynous students. The findings provide valuable insights into the metacognitive potential of androgynous individuals and the complex dynamics between gender identity and cognitive processes in the context of problem-solving. This study contributes to the broader discourse on metacognition, gender, and cognitive development, with implications for educators, policymakers, and researchers who strive to foster inclusive and effective educational environments.

Keywords: Metacognition, Androgynous, High School Student, Statistical Problem-Solving

Introduction

Metacognition, the ability to think about one's thought processes, has long been considered a fundamental cognitive skill essential for successful learning and problem-solving (Flavell, 1979). The developmental trajectory of metacognition, particularly during the formative years of adolescence, remains the subject of intense scientific research, which yields insights into the critical role of metacognition in academic achievement (Baker, 2016; Schneider & Lockl, 2002). Simultaneously, the understanding of gender identity has evolved beyond the traditional binary paradigm, recognizing its malleability and complexity, especially during adolescence (Archer, 2004; Diamond, 2002). Amidst this evolving landscape, the concept of androgyny has emerged, which encompasses individuals who have a gender identity that combines both masculine and feminine traits (Bem, 1974).

The rationale for this research is threefold. First, most Indonesians only recognize the male gender as masculine and the female gender as feminine, and anything outside of these two genders (androgyny) is abnormal or considered deviant (Belinda, 2022; Sihombing & Rakhmad, 2019). Second, androgyny has a higher level of cognitive flexibility on average, with the ability to change viewpoints and approaches quickly, tend to refuse to stick to one way of thinking and remain open to new ideas and concepts (Moshman, 2018). Third, metacognitive skills have a significant influence on students' success in problem-solving (Güner & Erbay, 2021), with the concept of problem-solving triggering students' metacognition (Kim et al., 2013). Interestingly, the intersection between metacognition and androgyny remains relatively uncharted in educational psychology and cognitive development.

As adolescents embark on a critical journey of self-discovery, the interplay between their evolving gender identity and metacognitive processes warrants closer examination. The notion of androgyny, which encompasses a balanced blend of traditionally masculine and feminine traits (Bem, 1974), introduces an exciting dimension to the discourse surrounding cognitive processes and problem-solving abilities. Although much research has been conducted to study middle school students' metacognitive development and gender (Hines & Kritsonis, 2011), little attention has been directed towards understanding how androgynous individuals utilize their unique blend of gender traits to enhance metacognitive strategies in solving mathematical problems, particularly in statistics.

As they encounter academic complexity, such as problem-solving tasks, secondary school students will be at a critical point in their cognitive maturation. Uncovering the metacognitive mechanisms used by androgynous secondary school students in the context of problem-solving is critical to advancing theoretical understanding and informing targeted educational interventions. This research is significant in several ways. First, it contributes to the growing discourse on metacognition and gender by shedding light on how androgynous high school students deal with cognitive challenges. Second, the findings can provide valuable insights for educators and educational policymakers to tailor pedagogical practices that tap into the metacognitive potential of not only feminine and masculine-gendered students but also androgynous students. Moreover, this research aligns with broader efforts to promote inclusivity and diversity in educational settings.

In summary, this research aims to unlock the metacognitive potential within the minds of androgynous high school students. By investigating the complex interplay between gender identity and metacognition, we aim to illuminate the path towards more effective cognitive development strategies, ultimately enriching the educational experience for these students and advancing our understanding of metacognitive processes during adolescence.

Literature Review

Metacognition, often called "thinking about thinking" (Flavell, 1979), is a multifaceted cognitive skill that includes awareness and regulation of one's cognitive processes. The importance of metacognition in education and cognitive development is well established. Adolescence, characterized by profound cognitive, emotional and social changes, is an essential period in the maturation of metacognitive abilities (Baker, 2016; Schneider & Lockl, 2002). During this stage, individuals acquire the capacity to monitor and regulate their thinking, thereby improving their problem-solving abilities and academic performance (Schraw & Moshman, 1995).

Metacognitive development in adolescence is closely related to the acquisition of self-regulation skills (Schunk & Zimmerman, 2013). Self-regulation involves setting goals, planning strategies to achieve them, monitoring progress, and making necessary adjustments (Zimmerman, 2013). As adolescents navigate the complexities of their academic endeavors, metacognitive strategies such as goal setting, self-assessment, and self-reflection become integral to their learning process (Efklides, 2011). However, this developmental trajectory is unique, with many individual differences. Variability in metacognitive abilities among adolescents can be attributed to cognitive development, motivation, and personality traits (Efklides, 2011). In addition, emerging research suggests that gender identity and expression may also play a role in shaping metacognitive development during adolescence.

Androgyny, a term introduced by Sandra Bem in 1974, challenges the traditional binary classification of gender identity. Androgynous individuals exhibit masculine and feminine traits that transcend conventional gender norms (Bem, 1974). Adolescence is a critical period in exploring and developing one's gender identity, characterized by increased fluidity and openness to diverse gender expressions (Archer, 2004).

The concept of androgyny has opened new avenues for understanding the complexity of gender identity in adolescents. It recognizes that gender is not an immutable binary construct but a dynamic and evolving aspect of individual identity (Gupta et al., 2009). Although previous research has explored various aspects of androgyny, such as its impact on self-esteem and psychological well-being (Spence & Helmreich, 1978), its intersection with metacognition remains relatively uncharted.

The influence of gender on metacognition has become an increasingly interesting topic in educational psychology. While early research showed gender differences in metacognitive behaviour, more recent research has emphasized the complexity of this relationship (Veenman et al., 2006). In particular, gender identity, which includes traditionally defined dimensions of masculinity and femininity, has been investigated as a potential modifier of metacognitive processes. Androgyny, a concept introduced by Bem (1974), characterizes individuals who exhibit a balanced blend of masculine and feminine traits, suggesting that they can employ various cognitive strategies in problem-solving contexts.

Previous research has explored metacognition in secondary school students, often focusing on gender as a variable of interest (Hart et al., 2008). These studies yielded mixed findings. Some studies suggest that females may exhibit higher levels of metacognitive awareness

(Efklides et al., 2018), while other studies have found no significant gender differences (Efklides, 2006). The variability in research results highlights the need for a more nuanced examination of gender-related factors, including statistical problem-solving ability in metacognitive processes among secondary school students.

The concept of androgyny offers a promising avenue to investigate the relationship between gender identity and metacognition. Androgynous individuals, characterized by their ability to draw on traditionally masculine and feminine traits, may have high cognitive flexibility that allows them to adapt their metacognitive strategies to different problem-solving contexts. This adaptability is potentially a unique metacognitive advantage in secondary school students, allowing them to meet challenges with various cognitive tools.

Methodology

Research Design

This research adopted a case study design with a qualitative descriptive approach to understanding the metacognitive processes used by androgynous high school students in statistical problem-solving (Creswell & Poth, 2016).

Participant

A total of 61 students were involved in selecting participants in this study. Participants for this study were drawn from science high schools within the same demographic range of math ability (medium) to ensure equal subjects in terms of math ability. The gender criteria of androgyny as the main subject and non-androgyny (masculine and feminine) as the comparison subject were identified based on the Bem Sex-Role Inventory (see Table 1). A purposive sampling technique was used to select participants who met these criteria to ensure the focus of the study was on androgynous individuals. Based on the math ability test and gender questionnaire, one androgynous student and two non-androgynous students (masculine and feminine) were selected. For the gender of androgynous students, more males than females were taken, while masculine students were taken with male gender and feminine students were taken with female gender (see Table 2).

Table 1. Gender distribution based on BSRI questionnaire results

Gender	Sex		%
	Male	Female	
Androgini	10	8	29.6
Maskulin	19	0	31.1
Feminin	1	23	39.3

Table 2. Participants selected based on TKM and BSRI

Subject	TKM Score	BSRI Score	Gender
S-1	78	$4{,}80_{\bar{M}} > 4{,}76_{\bar{F}} > 3{,}90_{\bar{N}}$	Androgynous student
S-2	77	$5{,}10_{\bar{M}} > 4{,}30_{\bar{F}} < 4{,}70_{\bar{N}}$	Non-androgynous student-1 (Masculine)
S-3	78	$3{,}80_{\bar{M}} < 4{,}98_{\bar{F}} > 4{,}20_{\bar{N}}$	Non-androgynous student-2 (Feminine)

Data Collection Method

The primary data collection method was semi-structured interviews based on a statistical problem-solving task. This approach allows for open-ended questions, allowing participants to articulate their metacognitive experiences and strategies freely (Bogdan & Biklen, 1997). Interview questions were designed according to predetermined indicators from the theoretical framework to elicit narratives of students' statistical problem-solving experiences, metacognitive awareness, and reflections on their androgynous identity about cognitive processes (see Table 3).

Table 3. Metacognitive Activity Indicators

Component	**Subcomponent**	**Indicators**
Metacognitive Knowledge	Declarative Knowledge	Explaining the difficulty level of the problem (DK)
	Procedural Knowledge	Explaining the strategy, method, formula or steps that will be used in solving the problem (PK)
	Conditional Knowledge	Explaining the reasons why and when to use a strategy, method, formula or steps in solving problems (CK)
Metacognitive Regulation	Planning	Explaining how to identify known and questionable information (P1) Finding the relationship between the problem and problems that have been solved before (P2) Determining the goal to be achieved (P3) Obtaining strategies, methods, formulas, or problem-solving steps (P4)
	Monitoring	Believing the strategy, method, formula, or steps chosen are correct (M1) Checking the correctness of the chosen strategy, method, formula, or steps (M2) Looking at the problem differently (M3) Checking the suitability between the plan made and the implementation (M4)
	Evaluating	Solving the problem differently. (E1) Checking whether the chosen strategy, method, formula, or steps can be applied to other problems or issues (E2) Assessing the way of thinking and working (E3) Assessing the achievement of goals (E4)

Data Analysis

This study used thematic analysis to identify, code, and analyze recurring themes and patterns in the interview transcripts (Miles et al., 2018). This process will involve coding the first-cycle code and the second-cycle code, followed by the development of themes and sub-themes based on the theoretical framework that has been built in metacognition indicators. Data triangulation was conducted during the interview and observation time to ensure the credibility and validity of the findings (Creswell & Creswell, 2017).

Research Results

Androgynous Student

The results of androgynous students' statistical problem-solving were based on the interview. Androgynous students guessed the value of x by following the known data pattern, so it is assumed that x = 80. A test is done to ensure it is correct by calculating the mean value, which must be the same as the median. Because the mean and median results are equal to 50, it is concluded that the value of x is 80. Furthermore, in the variance value claim, androgynous students use the variance formula for population data. There was a monitoring activity of the formula used, which initially used the divisor n, then changed to n-1, but in the end, it returned to n. In claiming the standard deviation value, androgynous students appear to use the formula correctly. However, because the previous variance value claim was wrong, the standard deviation value claim was wrong. Although the final result was wrong, metacognitive knowledge and metacognitive regulation activities appeared at this stage (see Figure 1).

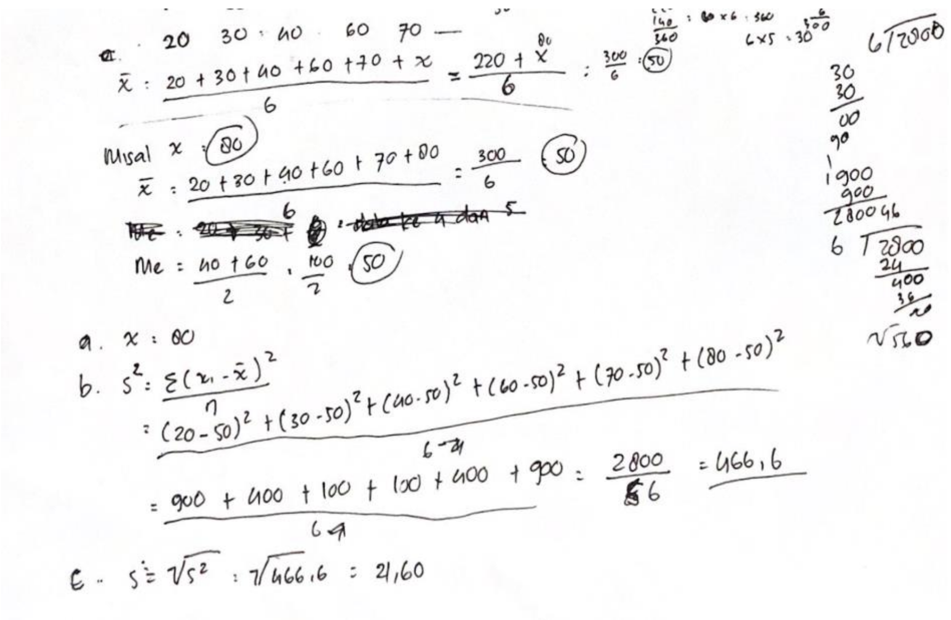

Figure 1: Statistics problem solving results of androgynous students

Since this research is a case study in problem-solving, we analyzed each problem-solving stage by code. When understanding the problem, androgynous students use metacognition knowledge and metacognition regulation at the metacognition knowledge of androgynous students' declarative knowledge that codes with their awareness of the problem's difficulty level and their understanding of the material according to their abilities. On procedural knowledge, the rest of the androgyny realized that the procedures needed were variance and standard deviation. In conditional knowledge, androgynous students realize why to use the mean and median formulas. In metacognition regulation activity at this stage, androgynous students realize the information of coin height data (see Figure 2).

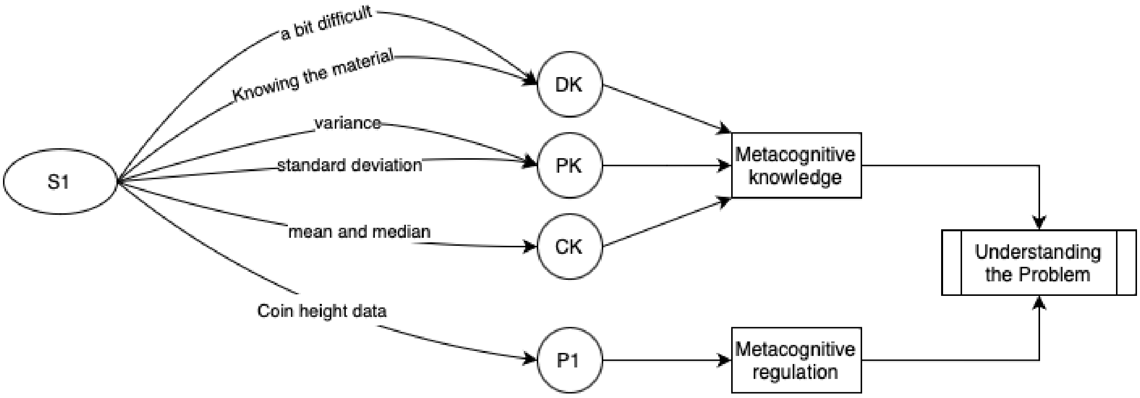

Figure 2: Metacognitive activities of androgynous student in understanding the problems

After the problem-understanding stage, we continued to explore the plans that androgynous students thought of to solve the problem. Metacognitive knowledge was used at this stage. Androgynous students explained their plan to use the variance formula and standard deviation. This is procedural knowledge. Androgynous students also explain why the mean and median formulas are needed in this problem, which is part of conditional knowledge. In addition, metacognitive regulation also plays a role in controlling the plans made. Androgynous students realize that this material has been studied before, and essential information in the problem can be used to answer the three problem questions. The formula and strategy to be used are also explained. This activity is part of the planning indicator. In addition, the planned strategy is adjusted to the requirements of the problem, so the monitoring activity indicator also appears at this stage (see Figure 3).

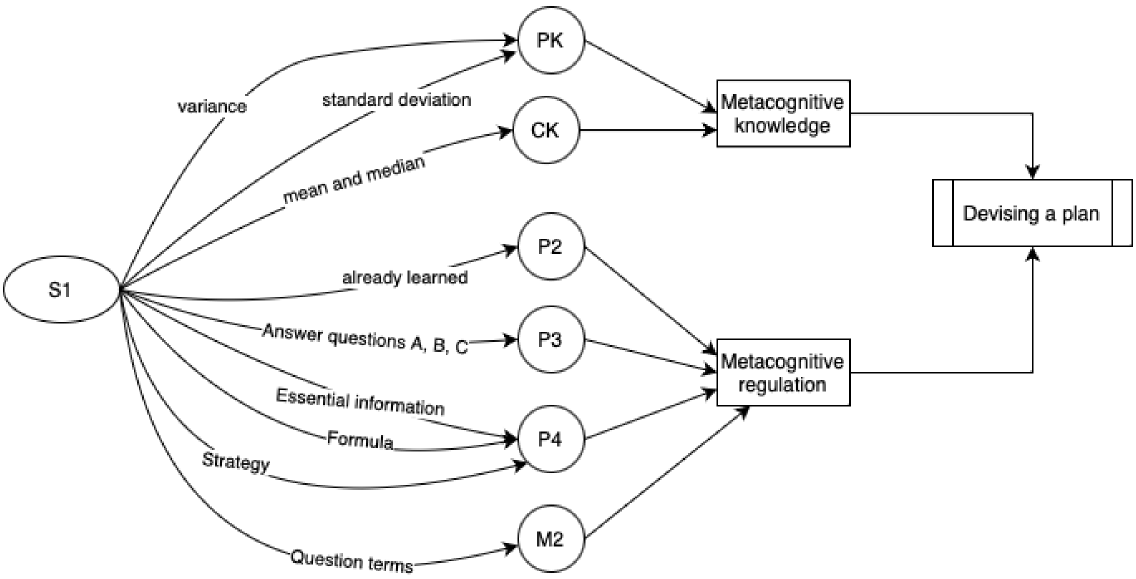

Figure 3: Metacognitive activity of androgynous student in devising a plan

The coding of interview data based on the problem-solving results at the plan implementation stage can be seen in this figure. Androgynous students are seen using all components of metacognitive knowledge when solving problems. Metacognitive regulation is also used. Androgynous students use all sub-indicators in planning (P1, P2, P3, P4). Androgynous students directly monitor their cognitive activities. This can be seen when three monitoring sub-indicators are confirmed during the interview (M1, M2, M4) (see Figure 4).

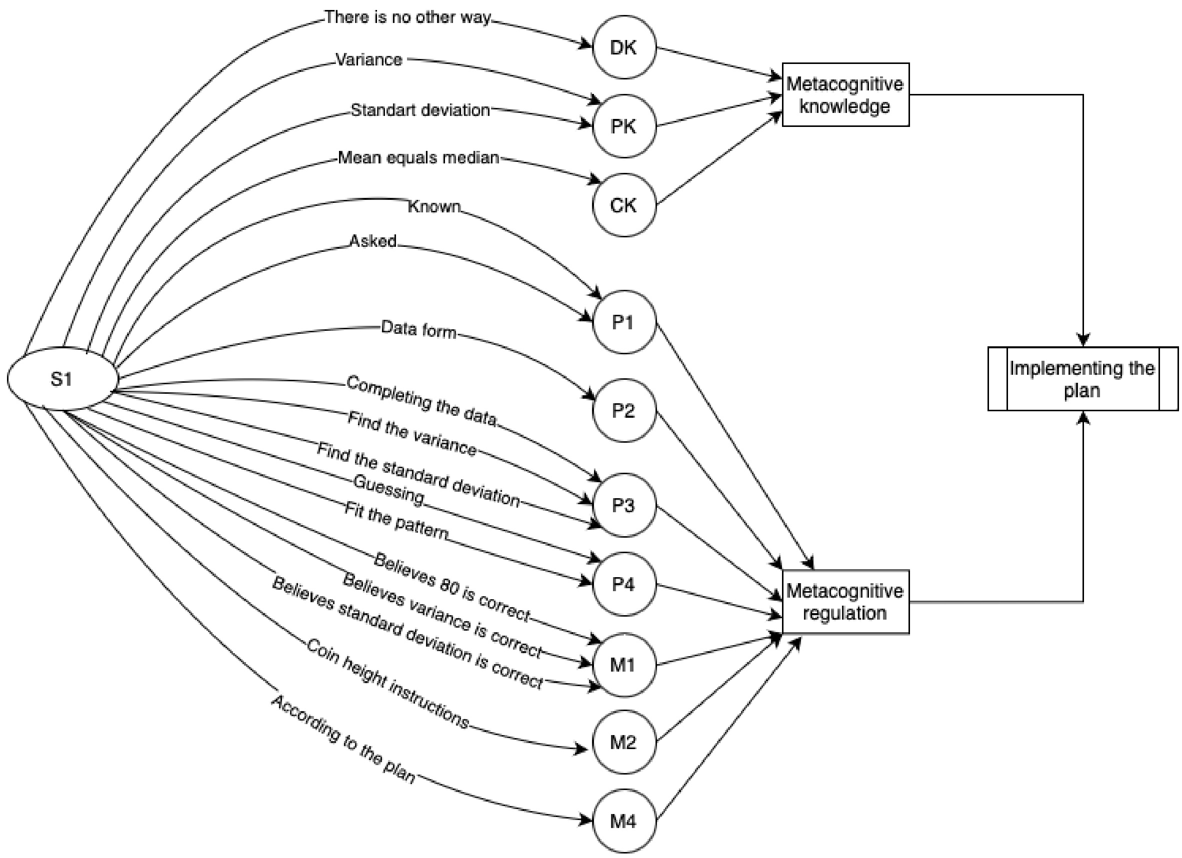

Figure 4: Metacognitive activity of androgynous student in implementing the plan

After solving the problem, androgynous students look back at the results of their work based on interviews; androgynous students realize that the method used is simple. This illustrates declarative knowledge. Androgynous students also check the suitability of the initial plan by looking back at the data and formulas used. This is a monitoring activity of metacognition regulation. The activity of rechecking the mean and median formulas, assessing the results of thinking that are good enough and according to plan, and the goals achieved are also carried out. This activity is part of the evaluation of metacognitive regulation (see Figure 5).

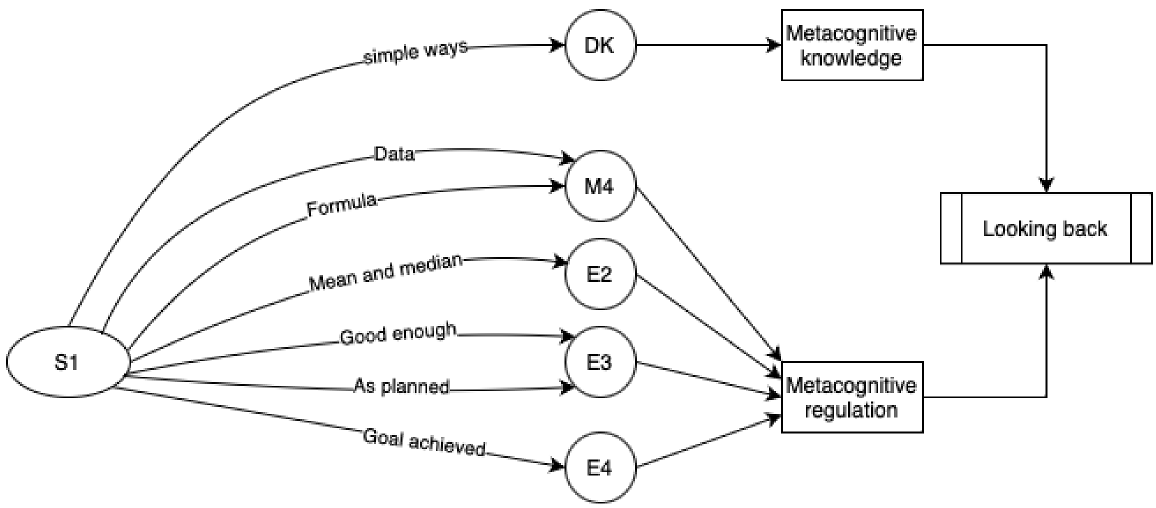

Figure 5: Metacognitive activity of androgynous student in looking back

As a comparison data of androgynous students' metacognition activities, we also analyzed the activity code of non-androgynous students based on the results of interviews based on the same statistical problem-solving task as the problem given to androgynous students. We present the results of the metacognitive activities of non-androgynous students in the form of a brief scheme to see the differences and similarities. So that the results are obtained as follows.

Non-androgynous Student-1

At the understanding of the problem stage, there was no difference in metacognition activities between androgynous and non-androgynous student-1. Non-androgynous student-1 used their declarative, procedural, and conditional knowledge. To control their cognition and understanding of the problem, non-androgynous student-1 use Planning (P1) (see Figure 6. a). In the devising a planning stage, there is a slight difference in metacognitive regulation; androgynous students use planning (P2), while non-androgynous student-1 do not use it. P2 is about seeing the relationship between the problem and the problem found before (see Figure 6. b).

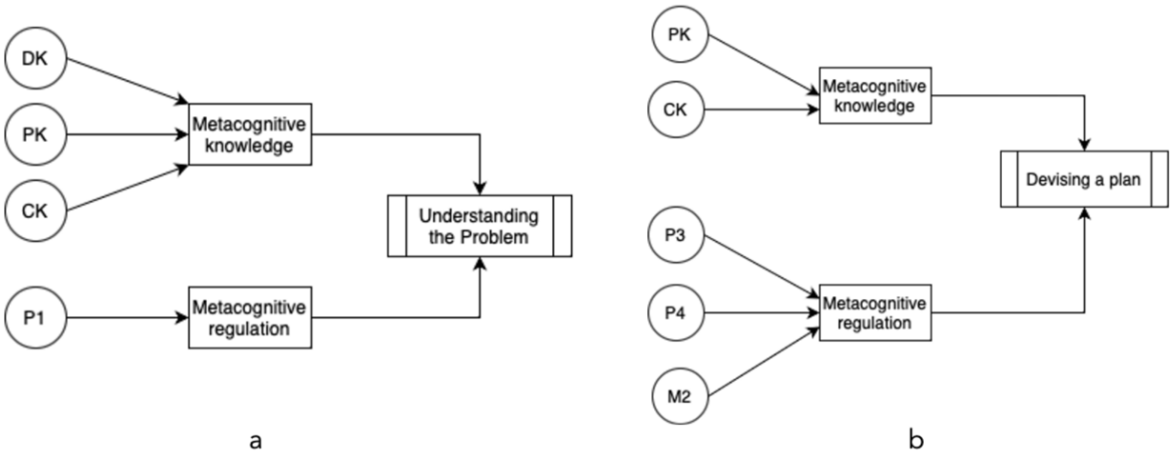

Figure 6: Metacognitive activities of non-androgynous student-1 in understanding the problem and devising a plan

In implementing the plan, there are differences in metacognitive activities in androgynous and non-androgynous student-1. Non-androgynous student-1 do not use their declarative knowledge, while androgynous students use declarative knowledge. This knowledge is an awareness of their problem-solving abilities and weaknesses (see Figure 7. a). Likewise, non-androgynous student-1 do not use planning (P2) when organizing cognition, while androgynous students use planning (P2) when looking at the single data form in the problem. Looking backstage, there is no difference; both use declarative knowledge, monitoring (M4), and evaluation (E2), (E3) and (E4) (see Figure 7. b).

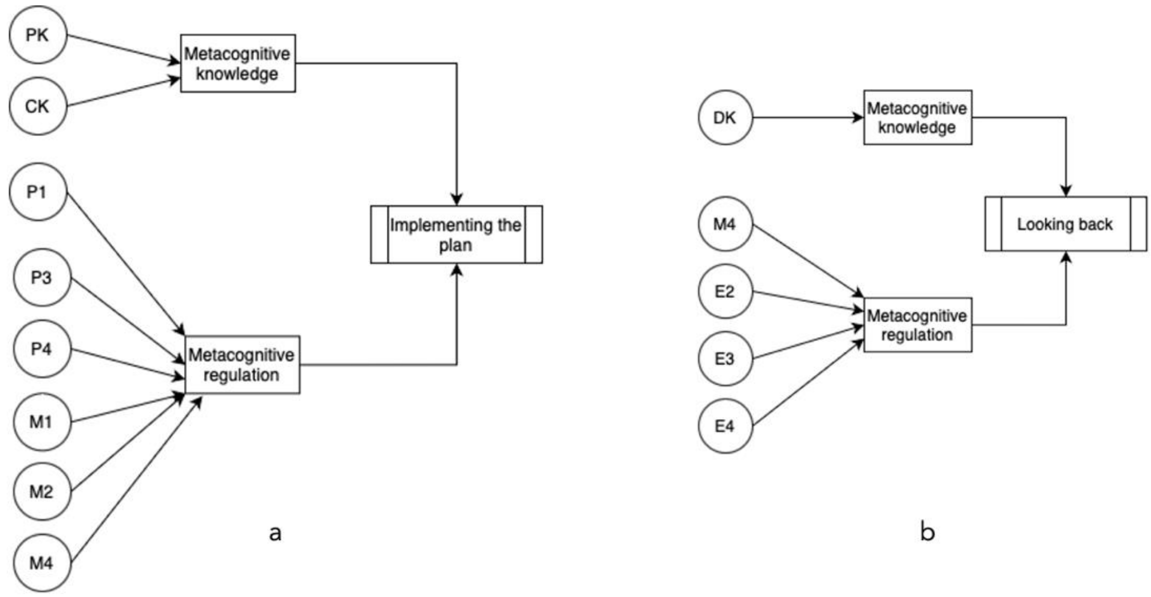

Figure 7: Metacognitive activities of non-androgynous student-1 in implementing the plan and looking back

Non-androgynous Student-2

At the stage of understanding the problem, there are differences in the metacognitive activities of non-androgynous student-2 and androgynous students, especially in metacognitive regulation. Non-androgynous student-2 use planning (P1, P2, P4) and monitoring (M4), while androgynous students only use planning (P1) (see Figure 8. a). At the devising a planning stage, there is a slight difference in metacognitive knowledge; non-androgynous student-2 only use conditional knowledge, while androgynous students use procedural and conditional knowledge (see Figure 8. b).

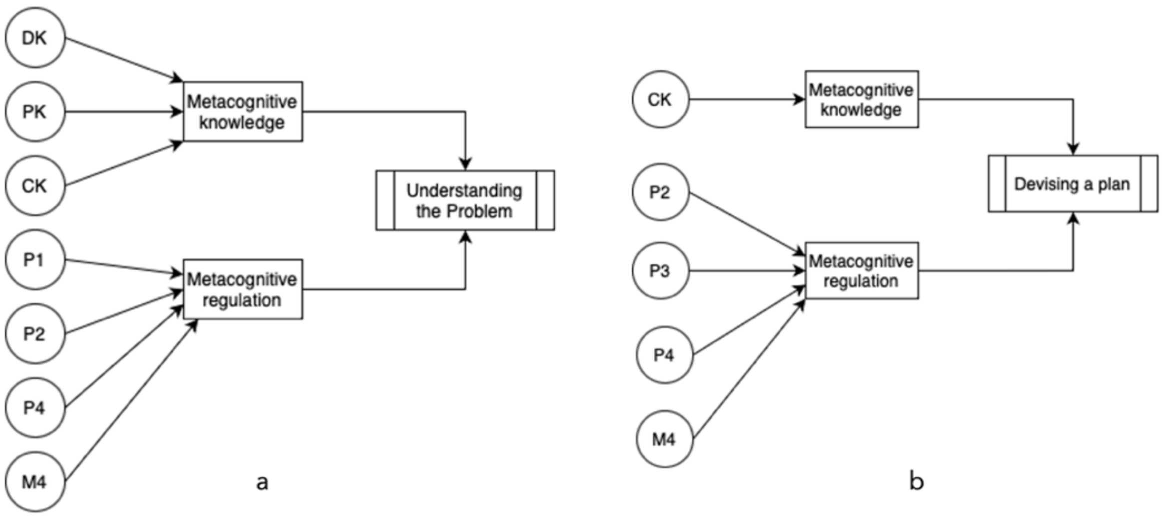

Figure 8: Metacognitive activities of non-androgynous student-2 in understanding the problem and devising a plan

In implementing the plan, there are differences in the metacognitive regulation activities of non-androgynous student-2 and androgynous students. Non-androgynous student-2 do not use planning (P2), while androgynous students use planning (P2). The next difference is that non-androgynous student-2 use evaluation (E4) while androgynous students do not use evaluation (E4) (see Figure 9. a). Looking backstage, there is no difference. Both use declarative knowledge, monitoring (M4), and evaluation (E2), (E3) and (E4) (see Figure 9. b).

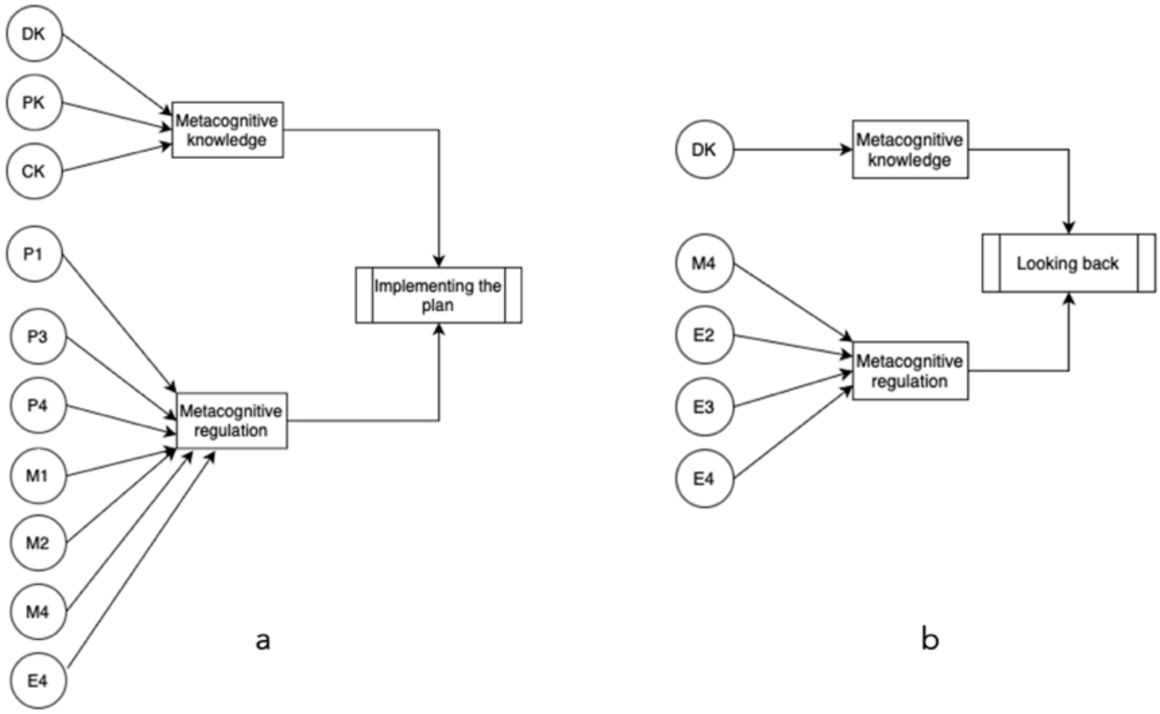

Figure 9: Metacognitive activities of non-androgynous student-2 in implementing the plan and looking back

Discussion

Although previous research has explored metacognitive processes in various contexts, little research specifically focuses on the relationship between androgyny and metacognition. Our findings align with previous research suggesting that metacognitive strategies are essential for academic success, especially in mathematical problem-solving (Schunk & Zimmerman, 2012). In addition, our study extends the existing literature by highlighting the potential influence of androgynous identity on metacognitive processes, shedding light on a previously under-explored area. Androgynous students can exercise reasonable cognitive control when solving math problems (Kark, 2020).

The androgynous students were able to maximize their declarative knowledge, procedural knowledge, and conditional knowledge abilities when understanding the problem, as well as the two non-androgynous students. This metacognitive knowledge seems connected and plays a role in understanding mathematical problems for androgynous and non-androgynous students (Braithwaite & Sprague, 2021).

The planning and monitoring that androgynous students do when solving problems provides a good transition of cognition, such as when planning to use the mean and median formulas to determine the unknown value of x and monitoring the pattern of data available to determine the solution, compared to non-androgynous students who use trial and error and guessing. All studies on gender role identity and resilience agree on the positive effects created by androgynous gender role identity on resilient behavior (Chakraborty & Das, 2013). Research on cognitive errors shows that non-resilient individuals maintain more cognitive errors. Thus, metacognitive regulation catalyzes resilient behavior (Kazdin, 2000).

The findings of this study have several implications for educators, curriculum developers and policymakers. First, understanding the metacognitive strategies used by androgynous students can inform the design of instructional approaches that meet their unique cognitive needs. By incorporating metacognitive skill-building activities into the curriculum, educators can empower androgynous students to become more effective problem solvers and critical thinkers. By unlocking the metacognitive potential of androgynous students, educators can create more inclusive learning environments that promote academic success and cognitive growth for all students, regardless of their gender identity.

Conclusion

This study highlights the metacognitive potential of androgynous secondary school students in the context of statistical problem-solving. The findings show that androgynous students have cognitive flexibility, smoothly transitioning between analytical and intuitive approaches based on problem characteristics. This is evidenced by metacognitive regulation activities (P3) analyzing data conditions and using guessing strategies (P4). All participants empowered metacognitive knowledge and metacognitive regulation to monitor and adapt cognitive processes during problem-solving, but androgynous students had greater control of metacognitive knowledge. This can be seen at each problem-solving stage; androgynous students use more metacognitive knowledge activities.

Androgynous students also showed goal-oriented planning in deciphering the complexity of statistical problems and aligning metacognitive strategies with goals. This can be seen in the interrelated activities between planning (P3, P4) and monitoring (M1, M2, M4) of metacognitive regulation. Planning is seen when androgynous students explain the data that must be completed to do this task, strategies to complete the data by guessing and seeing data patterns, and monitoring each work result based on the coin height requirement. Androgynous students are free from traditional cognitive stereotypes related to gender. This is evident because androgynous students can use a broader metacognitive approach than non-androgynous, incredibly non-androgynous student-1. In this regard, there are similarities with non-androgynous student-2, but the metacognitive activities of androgynous students in this study have illustrated that gender stereotypes against androgyny do not apply.

The findings of this study underscore the importance of recognizing and accommodating diverse gender identities in educational settings. Understanding the unique cognitive needs of androgynous students, educators can tailor instructional approaches to encourage the development of metacognitive skills. This study contributes to our understanding of metacognition and androgyny by shedding light on the metacognitive strategies used by androgynous high school students.

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