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Students' Mathematical Literacy in Statistical Problem Solving: Insights from Metacognition and Self-Efficacy

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Abstract

Mathematical literacy is essential in today's information age, particularly in understanding, interpreting, and applying numerical information in fields like statistical data analysis. Statistics, as a key branch of mathematics, plays a pivotal role in data interpretation and decision-making. However, many students struggle with fundamental statistical concepts including probability, hypothesis testing, and regression analysis, which hinders their ability to solve complex problems. This descriptive qualitative study examines the influence of metacognition and self-efficacy on students' statistical problem-solving abilities. Metacognition refers to awareness and regulation of one's cognitive processes, while self-efficacy pertains to individuals' belief in their problem solving capabilities. Both factors significantly impact mathematical performance. The research evaluates students' proficiency in statistical methods, with a focus on inferential statistics. The findings reveal that students with good metacognition and high self-efficacy excel in solving statistical problems, demonstrating a deep understanding of mathematical concepts and confidence in their application. Conversely, students with moderate metacognition and medium to low self-efficacy encounter challenges in critical reflection and in-depth evaluation, which adversely affects the quality of their result interpretation. Enhancing metacognition and self-efficacy is crucial for improving overall mathematical literacy, particularly in reflection and critical evaluation skills.

Keywords: mathematical literacy; statistics; metacognition; self-efficacy; statistical problem solving.

1 Introduction

Mathematical literacy has become a critical 21st-century skill, serving as a bridge between abstract mathematical concepts and real-world problem-solving [42, 53]. International assessments reveal striking disparities in mathematical proficiency across nations. High-performing education systems like Japan and Finland emphasize deep conceptual understanding, collaborative learning approaches, and the cultivation of metacognitive skills and self-efficacy [47, 21]. In contrast, developed countries such as the United States and United Kingdom continue to grapple with fundamental challenges including persistent skill gaps and widespread mathematics anxiety among students, despite having well-established education systems [10, 57]. Research from Denmark demonstrates how targeted metacognitive strategies can significantly enhance numeracy skills, providing valuable insights into effective pedagogical approaches [8].

The situation in developing nations presents additional layers of complexity. Zimbabwe's higher education system, for instance, struggles with numeracy challenges stemming from resource limitations and reliance on traditional teaching methodologies [68]. Indonesia represents a particularly compelling case study, exhibiting what appears to be a paradox in educational development. While facing similar obstacles to other developing nations - including prevalent rote-learning practices and underdeveloped metacognitive skills among students - Indonesia has implemented ambitious reforms such as the nationwide Minimum Competency Assessment (MCA) [52]. As the operator of Southeast Asia's largest education system, serving more than 45 million students [59], Indonesia's persistent stagnation in PISA rankings (ranking 73rd out of 78 countries with a score of 379, compared to the OECD average of 489) [46] despite substantial educational investment raises important questions about the relationship between policy implementation and learning outcomes in resource-constrained environments.

Indonesia's MCA framework places significant emphasis on Higher Order Thinking Skills (HOTS), particularly problem-solving and creative thinking [45, 65]. A crucial aspect of HOTS is problem-solving, where metacognition plays a pivotal role [51]. Metacognition, defined as the awareness and control of one's cognitive processes, is a strong predictor of academic success as it enables students to regulate and optimize their learning from early education through adulthood [49]. Students with well-developed metacognitive skills demonstrate greater adaptability in applying mathematical principles to complex problems [40]. Equally important is self-efficacy, an individual's confidence in their ability to succeed, which significantly influences learning outcomes. Research shows that students with higher academic self-efficacy are more likely to employ metacognitive strategies and persist when facing challenges [29]. When these two factors operate synergistically, they create a powerful framework for systematic problem-solving, fostering both resilience and adaptability in mathematical learning.

However, this theoretical potential has yet to translate into classroom reality. The MCA's HOTS focus has not produced substantial changes in teaching practices or meaningful improvements in students' self-efficacy [54, 56]. The scale of the challenge becomes evident when considering that approximately 80% of Indonesian students demonstrate inadequate proficiency in HOTS-related tasks [64]. This situation underscores the urgent need to investigate how metacognition and self-efficacy interact within the Indonesian educational context, particularly in domains requiring higher-order thinking.

The domain of statistics education serves as an ideal microcosm for studying these challenges, as it requires students to integrate multiple competencies including data collection, analysis, and inference-making [61]. At institutions like Universitas Nahdlatul Ulama (UNU) Purwokerto, affiliated with Indonesia's largest Islamic organization, Nahdlatul Ulama, which is also one of the largest Islamic organizations in the world [1], a clear pattern emerges: while students typically achieve competency in descriptive statistics, they encounter significant difficulties when working with inferential methods [33]. This disparity mirrors nationwide challenges in translating educational policy into effective classroom practice.

While prior work has investigated metacognition in isolation [15] or examined problem-based learning approaches separately [9], few studies have analyzed the combined impact of metacognition and self-efficacy on university-level statistical problem-solving. This study specifically addresses: "How do metacognition and self-efficacy influence students' mathematical literacy in formulating, employing, and interpreting statistical problems?" By integrating cognitive psychology with mathematics education research, this investigation offers actionable insights for comparable educational systems seeking to enhance statistical literacy through evidence-based pedagogical approaches.

2 Literature Review

2.1 Mathematical literacy

The concept of mathematical literacy has been acknowledged since at least 1944, although its first formal definition was introduced within the OECD-PISA framework in 1999, with subsequent revisions in later editions [41]. Related concepts, such as numeracy, quantitative literacy, mathematical proficiency, and mathematical competence, aim to describe and evaluate students' knowledge and abilities in critical domains, including mathematics, reading, and scientific literacy. Significantly, the PISA 2003 assessment placed a particular emphasis on mathematical literacy [44].

This framework emphasizes that the literacy approach seeks to define and evaluate mathematical knowledge and skills not solely based on mastery of the school curriculum but in terms of readiness for active participation in society. Drawing from the broader economic concept of human capital, the PISA studies define mathematical literacy as the capacity to identify and comprehend the role of mathematics in the world, make informed decisions, and engage with mathematics in ways that meet an individual's life needs as a constructive, thoughtful, and reflective citizen [43]. The components of this definition are further clarified in the same document, where the term world encompasses natural, social, and cultural contexts, an interpretation enriched by Freudenthal's body of work. The structure of PISA mathematical tasks is built around this definition.

2.2 Metacognition

Flavell [18] defines metacognition as an individual's awareness and understanding of cognitive processes. It involves actively monitoring and regulating these processes to achieve specific goals. In simple terms, metacognition can be described as "thinking about thinking" or "cognition about cognition" [22]. According to Flavell [19], metacognition is composed of two main components: metacognitive knowledge and metacognitive skills. Metacognitive knowledge refers to an individual's understanding of cognitive processes, including awareness of effective learning strategies and the ability to use them appropriately to achieve learning objectives [58]. This metacognitive knowledge is further categorized into three aspects: (1) strategic knowledge, (2) knowledge of cognitive tasks, and (3) self-knowledge [32].

Additionally, Schraw [58] explains that metacognition consists of two main components: metacognitive knowledge and metacognitive regulation, each containing several sub components. The sub components of metacognitive knowledge are: (a) declarative knowledge, which involves understanding one's own abilities, strategies, skills, and the necessary resources for achieving goals; (b) procedural knowledge, which pertains to knowing how to apply prior knowledge in practical situations; and (c) conditional knowledge, which involves understanding when and why specific procedures, skills, or strategies should be applied. On the other hand, metacognitive regulation includes the following sub components: (a) planning, which refers to the ability to organize and plan learning activities; (b) information management strategies, which involve organizing information relevant to the learning process; (c) comprehension monitoring, which is the ability to assess one's own learning progress and identify areas of difficulty; (d) debugging strategies, which involve employing strategies to correct errors during learning; and (e) evaluation, which refers to the ability to assess the effectiveness of one's learning strategies.

2.3 Self-Efficacy

According to Bandura [7], self-efficacy refers to an individual's belief in their ability to successfully solve specific problems. Children with high self-efficacy tend to demonstrate improved cognitive abilities [13, 34]. Supporting this, Skaalvik [34] suggest that high self-efficacy can enhance various personal competencies. In mathematics education, students' self-efficacy in mathematics is a crucial construct, historically acknowledged for its influence on educational outcomes [28]. Specifically, students with higher self-efficacy are more inclined to engage in productive behaviors, such as utilizing effective learning strategies, which contribute to successfully completing tasks.

Bandura [7] defines self-efficacy as the belief in one's abilities to organize and execute the actions necessary to achieve specific outcomes. In the context of mathematics learning, self-efficacy is understood as a context-specific assessment of an individual's confidence in their ability to successfully perform a particular mathematical task or solve a problem [24]. It includes students' reflections on their past achievements, self-assessments of their abilities, and personal evaluations of their future performance in mathematics tasks. This construct is crucial in determining students' engagement with mathematical tasks. Students are more likely to tackle tasks they believe they can succeed in, while avoiding those they perceive as beyond their capabilities. Mathematics self-efficacy affects not only the types of tasks students are willing to attempt, but also the effort they exert, their persistence in overcoming difficulties, and their overall determination [50, 66]. Therefore, mathematics self-efficacy acts as an internal motivator, encouraging students to successfully complete mathematical tasks.

2.4 Inferential Statistics

Inferential statistics involves drawing conclusions about a larger population based on sample data [61]. This branch of statistics enables researchers to estimate population parameters and test hypotheses using methods such as t-tests and z-tests. These techniques help inform decision making by determining whether sample data provides sufficient evidence to reject a null hypothesis. Hypothesis testing is a central aspect of inferential statistics, wherein researchers compare sample data to assumptions about a population. The process includes testing both null and alternative

Main components of a statistical hypothesis test:

1. Select appropriate test statistic T
2. Define null hypothesis H_0 and alternative hypothesis H_1 for T
3. Find the sampling distribution for T, given H_0 true
4. Choose significance level α
5. Evaluate test statistic t for sample data
6. Determine the p-values
7. Make a decision (accept H_0 or reject H_0)

	decision	
	accept H_0	reject H_0
H_0	**TN**	FN Type I Error
H_1	FN Type II Error	**TP**

Figure 1: Main components that are common to all hypothesis tests

hypotheses to evaluate the validity of assumptions based on the available data. The origins of hypothesis testing can be traced back to John Arbuthnot in 1710 [25, 23], with the modern framework developing through the contributions of statisticians like R.A. Fisher, Jerzy Neyman, and Egon Pearson [16].

Among the common types of hypothesis tests are one-sample and two-sample tests, which evaluate whether a sample mean differs significantly from a population mean or compare the means of two independent populations. The hypothesis testing process follows a logical sequence, consisting of seven key components that help researchers ensure the validity of their conclusions. The components of this procedure are further illustrated in Figure 1 [16].

2.5 Integrated Framework: Mathematical Literacy in Statistical Problem Solving, Metacognition, and Self-Efficacy

The PISA 2022 framework defines mathematical literacy as an individual's capacity to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts [48]. This definition emphasizes not only the functional use of mathematical knowledge, but also problem-solving, reasoning, and the ability to engage with mathematical content critically and reflectively. One of the core content areas in the PISA 2022 framework is uncertainty and data, which includes probabilistic thinking and statistical reasoning, essential components in solving problems involving inferential statistics. Thus, this study adopts the term mathematical literacy in statistical problem solving, specifically referring to students' ability to apply mathematical reasoning and statistical procedures when solving problems in inferential statistics, such as hypothesis testing and confidence interval estimation. Empirical evidence from ethnomathematics based problem solving research indicates significant improvements in students'creative thinking abilities following implementation, underscoring that engagement in culturally grounded and meaningful mathematical tasks strengthens reasoning, reflection, and mathematical decision making, which are key components of mathematical literacy in statistical problem solving [38].

While research on mathematical literacy has grown in Southeast Asia in recent years, bibliometric and content analyses show that most studies still focus on primary and secondary education contexts, often addressing general numeracy or descriptive statistics skills [36, 2]. In contrast, research in higher education, especially within the domain of inferential statistics, remains limited. Even more scarce are studies that integrate mathematical literacy with cognitive and affective constructs such as metacognition and self-efficacy. For example, research has investigated the relationship between mathematical literacy and self-efficacy [37], while other studies have explored metacognitive strategies and self-efficacy [5]. However, few, if any, studies in Southeast Asia, particularly in Indonesia, have examined how these three constructs interact simultaneously in the context of statistical problem solving in higher education. This gap highlights the need for an integrated framework that captures the complexity of students' reasoning, beliefs, and strategies in applied statistical contexts.

Metacognition refers to students' awareness and regulation of their own cognitive processes [19]. Previous studies indicate that effective mathematical problem solving is strongly supported by instructional approaches that emphasize active learning, personalization, and reflective practice, particularly through the development of pedagogical competencies and metacognitive awareness. Empirical findings further show that students' metacognitive profiles, including awareness, regulation, and evaluation processes, vary according to cognitive styles and play a critical role in determining success in solving complex mathematical problems that require sustained reasoning and accuracy [4, 31]. It enables students to plan, monitor, and evaluate their approach to problem solving. In the context of statistical problem solving, metacognition supports the identification of problem requirements, selection of appropriate statistical tests, and interpretation of results. Students who could clearly express their understanding of statistical problems were found to be engaging in metacognitive activities even before attempting to solve them [55]. More recent research confirms that students with high self-efficacy are more likely to activate metacognitive strategies, creating a mutually reinforcing relationship between confidence and reflective thinking [17, 6].

Self-efficacy, as conceptualized by Bandura [7], is a person's belief in their ability to perform a specific task successfully. In inferential statistics, where problems are often abstract and require layered reasoning, students with high self-efficacy are more likely to persist, remain motivated, and engage deeply with complex procedures. Alali and Wardat [3] found a strong correlation between students' self-efficacy and their mathematical literacy performance. Students who demonstrated strong metacognitive regulation and high self-efficacy achieved significantly better outcomes in solving complex problem tasks, as reported in recent research [27]. These findings suggest that self-efficacy is not only a predictor of academic persistence but also a key enabler of successful mathematical engagement.

Synthesizing these perspectives, this study proposes a theoretical interaction in which mathematical literacy in statistical problem solving is shaped by both metacognitive regulation and self-efficacy beliefs, as illustrated in Figure 2. Metacognition drives the strategies students use in reasoning through statistical concepts, while self-efficacy sustains motivation and effort during the problem-solving process. This relationship is strongly mediated by cognitive and affective skills, and students with higher levels of mathematical literacy tend to exhibit higher academic performance, as supported by findings from Haeruman [26].

Despite growing evidence, very few studies in the Southeast Asian context have empirically tested this integrated model, particularly within inferential statistics learning. Therefore, this study addresses a critical gap in the literature by adopting a conceptual framework that positions mathematical literacy in statistical problem solving as the product of the dynamic interplay between metacognition and self-efficacy, two foundational constructs necessary for effective mathematical reasoning in higher education.

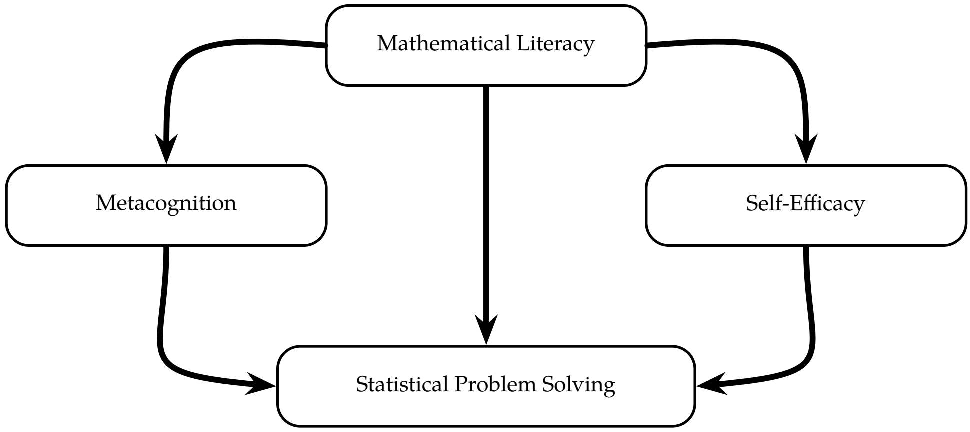

Figure 2: Conceptual model illustrating the roles of metacognition and self-efficacy in shaping students' mathematical literacy in statistical problem solving

3 Materials and Methods

3.1 Data Collection

To provide deeper context regarding the characteristics of the participants involved in this study, demographic information of prospective research subjects from the 2022 cohort of the Mathematics Study Program at UNU Purwokerto is presented in Table 1. This demographic data comprise gender, age, and Grade Point Average (GPA). The inclusion of this information aims to enhance the transferability of the findings and to offer a more comprehensive understanding of the participants' backgrounds, which may influence their patterns of thinking and their ability to solve statistical problems.

This study employs a descriptive research design with a qualitative approach, focusing on data from statistical problem-solving tests and interviews with selected research subjects to provide a detailed, in-depth description of students' literacy abilities based on metacognition and self-efficacy. Conducted in the even semester of the 2023/2024 academic year, the study includes undergraduate students from the Mathematics Study Program at UNU Purwokerto, specifically from the class of 2022. Subjects were chosen based on their metacognition levels and self-efficacy categories, assessed using the Metacognitive Awareness Inventory (MAI) questionnaire and a separate self-efficacy questionnaire, respectively.

Ethical approval for this study was obtained from the Research Ethics Committee of Universitas Nahdlatul Ulama Purwokerto (Ethics Approval No. 016/UNU-PWT.8/UM/2024, dated June 1, 2024). All participants provided voluntary informed consent prior to data collection, and confidentiality was strictly maintained throughout the data collection and analysis processes.

The selected subjects were further identified based on the following criteria: (1) students from the class of 2022 who had completed statistics-related courses, which would enable them to solve inferential statistics problems, specifically Hypothesis Testing for One and Two Population Means; (2) students observed to have strong problem-solving abilities and communication skills to accurately express their mathematical literacy abilities. Data were collected using the MAI question-

Table 1: Participant Demographic Information for the 2023/2024 Academic Year

Participant Code	Gender	Age	GPA
KS	Male	21	3.45
MS	Female	21	3.89
HS	Male	21	3.51
AN	Female	21	3.90
WS	Male	21	3.87
PW	Female	21	3.79
RA	Male	22	3.87
RG	Female	20	3.83
SH	Female	22	3.27
SA	Female	21	3.17
FA	Male	20	3.75
SY	Female	21	3.87
KN	Female	21	3.18
IR	Male	21	3.07
NA	Female	21	3.02
DA	Female	23	3.47
IN	Female	21	3.73

naire, the self-efficacy questionnaire, statistical problem-solving tests, and task-based interviews. The MAI rubric, the self-efficacy questionnaire, and statistical problem-solving tests used to select research subjects are discussed in detail below.

3.1.1 MAI Questionnaire Instrument

The MAI rubric, adapted from Schraw and Dennison [58, 14], categorizes metacognition into three levels: good, moderate, and poor. One representative was chosen from each level, resulting in three subjects categorized by metacognition.

Before the MAI questionnaire was distributed to the prospective research subjects, a translation and back-translation process was conducted. This step was necessary because the questionnaire was originally developed in English, requiring linguistic adaptation to ensure its appropriateness for use in Indonesian. To ensure the accuracy and validity of the translation, two language experts were involved: a lecturer in English and a lecturer in Indonesian from UNU Purwokerto, both of whom specialize in linguistics.

This psychological test comprises 37 statements for participants to complete. Metacognitive knowledge includes 17 statements, with subcategories of declarative knowledge (8 statements), procedural knowledge (4 statements), and conditional knowledge (5 statements). Metacognitive experiences or skills are represented by 20 statements: planning skills (7 statements), monitoring skills (7 statements), and evaluation skills (6 statements). The maximum score for the test is 37, while the minimum is 0. Table 2 outlines the criteria used to determine if subjects possess good, moderate, or poor levels of metacognitive components.

The metacognition questionnaire measures the metacognitive components of students using statements to which subjects respond with either true or false as indicated in Table 3. If a student selects true for a metacognition questionnaire statement, they receive a score of 1; if false, they

Table 2: The Components of Metacognitive Awareness Inventory (MAI)

Component	**Item Numbers**
Metacognitive Knowledge	
1. Declarative knowledge	5, 9, 11, 14, 15, 18, 27, 35
2. Procedural knowledge	3, 12, 24, 28
3. Conditional knowledge	13, 16, 23, 26, 30
Metacognitive Experience	
1. Planning skills	4, 6, 8, 20, 21, 33, 34
2. Monitoring skills	1, 2, 10, 19, 25, 29, 36
3. Evaluating skills	7, 17, 22, 31, 32, 37

receive a score of 0. Student metacognitive abilities are then classified by the indicators shown in Table 4.

Table 3: Metacognition Questionnaire Scoring Guide

Answer Category	**Scale**
True	1
False	0

Table 4: Metacognitive Components and Their Categories

Component	**Good**	**Moderate**	**Poor**
Metacognitive knowledge			
Declarative knowledge	6–7	3–5	0–2
Procedural knowledge	4–5	2–3	0–1
Conditional knowledge	4–5	2–3	0–1
Metacognitive experience			
Planning skills	6–7	2–5	0–1
Monitoring skills	6–7	2–5	0–1
Evaluating skills	5–6	2–4	0–1

Using the Likert scale, the categorization of metacognition is divided as follows:

1. Good: 25-37
2. Moderate: 13-24
3. Poor: 0-12

From each level, one student was selected as a research subject, resulting in three subjects based on metacognitive abilities.

3.1.2 Self-Efficacy Questionnaire Instrument

According to Bandura [7], self-efficacy consists of three dimensions: level, strength, and generality. The self-efficacy questionnaire was created based on these indicators, comprising 13 psychological test statements, as outlined in Table 5.

Table 5: Self-Efficacy Questionnaire Framework

Indicator	**Item Numbers**
Level dimension	1, 2, 3, 4, 5
Strength dimension	6, 7, 8, 9, 10
Generality dimension	11, 12, 13

Before the questionnaire was distributed, validity and reliability tests were conducted on the prepared questionnaire to ensure valid and reliable research results. For the instrument validity test, the researcher selected a sample of 30 students to pilot the instrument. The data from the trial were then calculated using the product moment correlation formula [11] as follows.

$$r_{xy} = \frac{N(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[N(\sum X^2) - (\sum X)^2]\,[N(\sum Y^2) - (\sum Y)^2]}} \tag{1}$$

Where: r_{xy} is the correlation coefficient between the item score and the total construct score; N is the total number of respondents; X is the score of an individual item; Y is the total score of the construct; $\sum X$ is the sum of item scores; $\sum Y$ is the sum of total construct scores; and $\sum XY$ is the sum of the products of X and Y.

After the calculations were completed, the obtained r values for each questionnaire item were compared with the critical r value (r table). The r table value was determined by first establishing the degrees of freedom (df) and the level of significance. The degrees of freedom were calculated using the formula df = N–2; with N = 30, the resulting df was 28. A significance level of 5% was applied. Based on the Pearson product-moment correlation table at the 5% significance level and df = 28, the critical r value was 0.374. An item was considered valid if the calculated r value was greater than or equal to the r table value, indicating a significant correlation. Conversely, items with calculated r values lower than the r table value were considered invalid. The detailed results of the instrument validity test are presented in Table 6.

Table 6: Self-Efficacy Questionnaire Instrument Validity Test

Item No.	$r_{\text{calculated}}$	r_{table}	**Conclusion**	**Item Variance**
1	0.43646	0.374	Valid	1.3974
2	0.57298	0.374	Valid	1.1026
3	0.38027	0.374	Valid	1.0947
4	0.44125	0.374	Valid	0.7868
5	0.59845	0.374	Valid	0.8947
6	0.57767	0.374	Valid	1.9053
7	0.52949	0.374	Valid	0.3658
8	0.55126	0.374	Valid	1.2105
9	0.46767	0.374	Valid	0.8526
10	0.42154	0.374	Valid	0.2526
11	0.48167	0.374	Valid	1.1474
12	0.68318	0.374	Valid	1.5684
13	0.45054	0.374	Valid	0.4316
Total				**13.0105**

Next, to measure the reliability of the questionnaire instrument, the Cronbach's Alpha formula [62] was used as follows:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k} \sigma_i^2}{\sigma_t^2}\right) \tag{2}$$

Based on the results of the instrument validity test, the following values were obtained: $k = 13$, $\sum \sigma_i^2 = 13.0105$, and $\sigma_t^2 = 40.24$. These values were then substituted into Equation (2) to calculate the reliability coefficient (α) as follows:

$$\begin{aligned}\alpha &= \left(\frac{13}{13-1}\right)\left(1-\frac{13.0105}{40.24}\right)\\ &= \left(\frac{13}{12}\right)(1-0.323)\\ &= 1.083 \times 0.677\\ &= 0.733\end{aligned} \tag{3}$$

Based on the results of the instrument reliability calculation, the self-efficacy questionnaire is considered reliable according to the testing criteria, as the reliability coefficient (α) exceeds 0.7 [62].

This instrument uses a Likert scale, commonly used to measure individual attitudes, opinions, and perceptions of an object or phenomenon [30]. The responses range from "Strongly Agree" (SA) to "Strongly Disagree" (SD), with corresponding values: SA = 5, A = 4, N = 3, D = 2 and SD = 1 for positive statements; reverse values apply for negative statements. Self-efficacy levels were categorized into high, medium, and low based on a questionnaire referencing Bandura's self-efficacy indicators [7, 63]. One representative was selected from each category, giving three subjects based on self-efficacy levels. Self-efficacy categories were determined using the mean (M) and standard deviation (SD) calculated with Microsoft Excel, using the following criteria.

1. If a the score of respondent score is equal to or above M + SD, they are categorized as high (H).
2. If the score is between M+SD and M-SD, they are categorized as medium (M).
3. If the score is equal to or below M-SD, they are categorized as low (L).

From these categories, three research subjects were selected, one from each level of self-efficacy.

3.1.3 Statistical Problem Solving Tests

Subjects completed two written tasks related to Hypothesis Testing, coded as S1 for One Population Mean and S2 for Two Population Means. Table 7 displays the problems presented.

While solving these problems, the subjects were asked to verbally communicate their thoughts and reasoning processes. Following this, in-depth interviews were conducted at each stage of mathematical literacy to further assess the subjects'abilities in alignment with predefined literacy indicators: formulate, employ, and interpret. The description and specific indicators for each of these mathematical literacy skills, which formed the basis of the interview guidelines, are presented in Table 8 [48], adapted from the PISA 2022 Mathematics Framework.

Table 7: Inferential Statistic Problems

No.	Code	Question
1.	S1	**Topic: Hypothesis Testing of One Population Mean** A researcher plans to collect data on the body weight of residents in the village of Makmur Sentosa. It is known that the body weight of residents in this village follows a normal distribution with a standard deviation of 10 kilograms. Due to time constraints, a random sample of 30 residents is taken, and it is found that their average body weight is 50 kilograms. Using a 5% significance level, test the hypothesis that the average body weight of residents in Makmur Sentosa village is less than 52 kilograms.
2.	S2	**Topic: Hypothesis Testing of Two Population Means** Forty-four apple orchards in Batu City and forty apple orchards in Poncokusumo were randomly selected as samples to test the hypothesis that the average annual productivity of apple orchards in Batu City is higher than that of apple orchards in Poncokusumo. Based on these samples, it was found that the productivity of apple orchards in Batu City is 84 tons with a standard deviation of 2 tons, while in Poncokusumo it is 78.6 tons with a standard deviation of 2.5 tons. At a 5% significance level, does the sample support the hypothesis that the productivity of apple orchards in Batu City is higher than in Poncokusumo?

Table 8: Mathematical Literacy Indicators

Aspect	Indicator
Formulate	**Formulate real problems into a mathematical context.** 1. Ability to mention important information in questions. 2. Ability to explain how the solution steps and concepts will be used. 3. Ability to understand and explain the relationship between language, symbols, and problem context so that it can be presented systematically.
Employ	**Using mathematical concepts, facts, and procedures in solving problems.** 1. Ability to design and implement strategies to find mathematical solutions. 2. Ability to apply facts, rules, algorithms, and mathematical structures to create solutions. 3. Ability to make generalizations based on mathematical procedures to find solutions.
Interpret	**Interpret, apply, and evaluate the results of solving mathematical problems.** Ability to interpret the reasons why the conclusions reached are appropriate to the context of the given problem.

3.2 Data Analysis

The analysis of the research subjects' mathematical literacy abilities in each category of metacognition and self-efficacy was based on corresponding mathematical literacy indicators. After data collection, this study employed the data analysis model of Miles, Huberman, and Saldana [39]. The steps of data analysis involve data condensation, data display, and conclusion drawing, as presented in Figure 3 and described as follows.

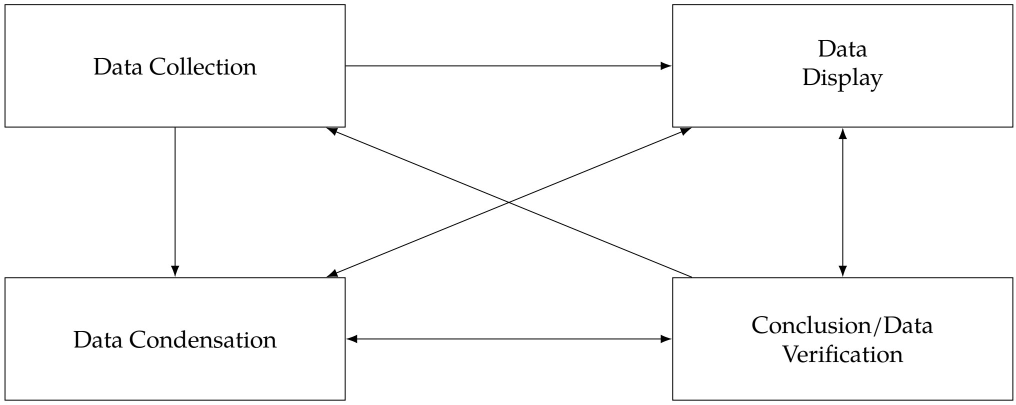

Figure 3: Interactive Data Analysis Model

1. Data Condensation or Reduction: In this step, relevant information is selectively extracted, while data that are not pertinent to the study are eliminated. As a result, the condensed data become more focused, reduced in volume, and directed toward the core issues, thereby providing a clearer understanding of the research problem.

2. Data Display: The condensed data is then presented descriptively according to the predetermined indicators of mathematical literacy ability. In this step, the information is systematically organized to explain and address the research questions, specifically describing students' mathematical literacy abilities based on metacognition and self-efficacy.

3. Conclusion Drawing/Verification: After the data analysis process, data verification is conducted to ensure accuracy. This study utilized method triangulation, employing multiple data collection techniques to corroborate findings. Problem-solving tests and semi-structured interviews were used to illustrate students' mathematical literacy abilities through the lenses of metacognition and self-efficacy. Additionally, member checking was carried out by returning the interpreted data to the participants to confirm the credibility and accuracy of the findings. After data verification, final conclusions were drawn regarding students' mathematical literacy abilities based on metacognition and self-efficacy categories for each indicator.

4 Results

4.1 Selection of Research Subjects

The prospective research subjects in this study were students from the Mathematics Program at Universitas Nahdlatul Ulama Purwokerto, Class of 2022, selected based on their metacognition and self-efficacy levels. The results of the MAI rubric analysis of these prospective research subjects are presented in Table 9.

Based on the analysis of the MAI rubric results and considerations of communication skills, two subjects were selected according to their metacognition levels. One subject was categorized as having moderate metacognition (Subject IR), while the other was categorized as having good metacognition (Subject RG). The poor metacognition category was not identified among the prospective research subjects, as previously determined; therefore, the findings of this study focus solely on the analysis of the good and moderate metacognition categories. The results of the self-efficacy questionnaire analysis are presented in Table 10.

Table 9: Results of the MAI Rubric Analysis

No.	Subject Initials	Metacognitive knowledge			Metacognitive experience			Score	Category
		Declarative	Procedural	Conditional	Planning	Monitoring	Evaluating		
1	KS	7	4	5	7	7	6	36	Good
2	MS	7	4	5	7	7	6	36	Good
3	HS	7	3	3	4	6	5	28	Good
4	AN	6	3	4	6	6	4	29	Good
5	WS	6	3	3	6	5	6	29	Good
6	PW	7	3	3	4	6	5	28	Good
7	RA	6	3	4	6	6	4	29	Good
8	RC	6	4	5	7	7	6	35	Good
9	SH	7	3	3	4	6	5	28	Good
10	SA	6	4	5	7	7	6	35	Good
11	RA	6	3	3	6	5	6	29	Good
12	SY	7	3	3	4	6	5	28	Good
13	KN	2	2	3	4	4	5	20	Moderate
14	IR	5	3	3	2	4	6	23	Moderate
15	NA	7	3	3	4	6	5	28	Good
16	DA	6	3	4	6	6	4	29	Good
17	IN	6	3	3	6	5	6	29	Good

Table 10: Results of Self-Efficacy Questionnaire Analysis

No	Name Initials	Score	Category
1	AN	37	Low
2	WS	41	Medium
3	SY	37	Low
4	FA	45	High
5	RG	44	Medium
6	SA	40	Medium
7	NA	39	Medium
8	IN	39	Medium
9	DA	50	High
10	HS	42	Medium
11	KS	38	Low
12	MS	43	Medium
13	PW	43	Medium
14	RA	44	Medium
15	SH	43	Medium
16	KN	40	Medium
17	IR	44	Medium
Sum		806	
Mean (M)		47.41176	
Standard Deviation (SD)		4.395073	
M + SD		52	
M - SD		43	

Based on the calculation of the mean and standard deviation from the table above, the categories of students' self-efficacy were determined based on their questionnaire scores as follows:

1. High: if the respondent's score is ≥ 52.

2. Medium: if the respondent's score is between 43 and 52.
3. Low: if the respondent's score is ≤ 43.

From the analysis of the self-efficacy questionnaire and considerations of communication skills, three research subjects were selected to represent the high, medium, and low self-efficacy categories. The subject with high self-efficacy is referred to as Subject FA, the subject with medium self-efficacy as Subject IN, and the subject with low self-efficacy as Subject AN.

4.2 Results of Data Analysis Based on Metacognition and Self-Efficacy

The results of the data analysis collected for each research subject category are described in detail as follows:

4.2.1 Based on Metacognitive Levels

1. **Subject with Good Metacognition (Subject RG)**

   The subject demonstrates a strong ability to formulate problems from real-world contexts into mathematical models when solving Problem S1. However, when solving Problem S2, the subject displays a more detailed approach in formulating and simplifying the model, reflecting a deeper understanding of the problem's complexity. Additionally, in the employ aspect, the subject exhibits flexibility in identifying and correcting errors, which is a key indicator of metacognitive skills. The subject applies both algorithms and manual calculation methods to solve the problems and showcases strong analytical skills by evaluating the results through comparisons with similar examples.

   However, while solving Problem S1, the subject initially made an error in formulating the hypothesis, which impacted the final decision. Upon recognizing this mistake, the subject successfully corrected the hypothesis and ultimately resolved the problem correctly. This is evidenced by the following excerpts from responses and interview data, as presented in Figure 4.

P1-09: How do you evaluate/correct your solution to ensure you get the correct answer?
RG1-09: I evaluate my solution by comparing my answers with similar examples from the first step to the conclusion, using trusted sources to ensure accuracy.
P1-10: Please recheck the hypothesis. The question asks if the weight is ≤ 52. What are the rules for H_0 and H_1? The hypothesis affects the results and conclusion.
RG1-10: So it's just less than and greater than, right? Because I saw some sources using the "$\neq$" symbol.
P1-11: Use the one we have agreed upon. Even if the sources differ, the final result should show the same value.
RG1-11: I think I made a mistake; my hypothesis was reversed. H_0 should be $\leq$.
P1-12: So, what do you want to correct?
RG1-12: I should correct it from the decision point, or from the beginning to the end-are they all swapped?
P1-13: Check where the impact is.
RG1-13: It affects the decision and conclusion. So the errors and corrections should be on the hypothesis, decision, and conclusion parts.
P1-14: Yes.
RG1-14: (Correcting the answer)

Figure 4: Excerpts from Subject RG's Interview

After realizing the error, the subject corrected their response by reversing the hypotheses H_0 and H_1. This correction is evident from the excerpts of the initial and revised answers shown below.

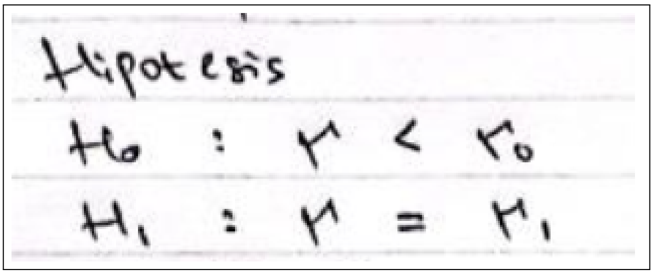

Figure 5: Initial Answer Excerpt of RG in S1

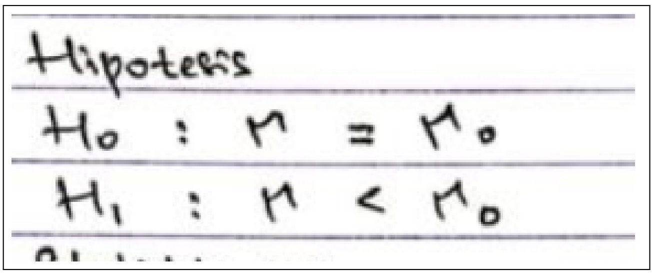

Figure 6: Final Answer Excerpt of RG in S1

In solving Problem S2, the subject demonstrates greater confidence and accuracy in applying the required steps, with no significant errors observed. Regarding the interpret aspect, the subject consistently and confidently concludes the results of both hypothesis tests. The subject is able to accurately interpret each critical element of the problem.

From the above analysis, it can be concluded that the subject with good metacognitive skills demonstrates strong performance across all indicators of mathematical literacy (formulate, employ, and interpret) in solving both single-population and two-population hypothesis tests. The subject effectively handles the complexity of the problems, corrects errors as needed, and consistently interprets the results accurately. The key differences observed include a more detailed and thorough formulation process in the two-population hypothesis test and enhanced confidence in the application and interpretation of the testing procedures.

2. **Subject with Moderate Metacognition (Subject IR)**

   In solving Problems S1 and S2, the subject demonstrates similar patterns in the aspects of formulate, employ, and interpret. The subject shows a sufficient basic understanding but struggles with deeper reflection and evaluation, which are crucial aspects of metacognition. The subject tends to follow procedures mechanically without fully understanding the context or the interrelationships between relevant concepts.

   In the formulate aspect, the subject often experiences confusion when converting real-world problems into mathematical models, indicating a lack of in-depth understanding. The subject can identify key information such as standard deviation, alpha, mean, and sample size, but remains uncertain about how to transform these into a mathematical model. For example, when asked to explain how a problem can be simplified, the subject requires further guidance to understand the concept of the alpha symbol and its relationship to the mean. This is evident from the excerpt of the subject's interview when solving Problem S1 below.

P1-03: What important information do you know about this problem?
IR1-03: The information includes standard deviation, alpha, mean, and sample size.
P1-04: How do you translate this problem into a mathematical model and present it in a simplified form?
IR1-04: What do you mean, Ma'am?
P1-05: What does alpha represent? It's a symbol, right? So, what does it relate to?
IR1-05: It relates to the mean, such as alpha equals 50, sample size n, H_0, standard deviation is 10, and Z-table.

Figure 7: Excerpts from Subject IR's Interview in S1

In the employ aspect, the subject is able to follow procedures but lacks deeper evaluation of the results. The subject follows standard procedures, such as determining the null hypothesis (H_0) and the alternative hypothesis (H_1), calculating the Z-test statistic, and comparing it with the Z-table. Although the subject successfully follows the procedural steps, there is a lack of evaluation strategies, as the subject relies solely on recalculations without checking the logic or consistency with the problem context. The formulate and employ abilities improve when transitioning from S1 to S2, particularly in understanding the problem context and applying appropriate procedures.

In the interpret aspect, the subject initially relies on a formal approach that is less suited to the problem but is able to correct the mistakes after receiving feedback. The subject also still shows uncertainty and lacks confidence in drawing conclusions, especially in S1. This suggests that while the subject has a sufficient foundational knowledge, there is a need for improvement in more critical evaluation and interpretation of the results. Overall, the subject, with moderately good metacognitive skills, is able to solve statistical problems mechanically but requires further development in deeper reflection and evaluation to enhance their mathematical literacy skills.

4.2.2 Based on Self-Efficacy Category

1. **Subject with High Self-Efficacy (Subject FA)**

   In the formulate aspect, the subject demonstrates a strong ability to identify the real-world context of the given problems when solving Problems S1 and S2. The subject consistently translates real-world problems into mathematical models by specifying important variables such as sample size, mean, and standard deviation. In both cases, the subject also understands the steps required to perform hypothesis testing, although the two-population hypothesis test introduces additional complexity by comparing two different populations. This is evident from the following excerpt of the subject's interview when solving Problem S2.

P1-06: What concepts and steps will you use to solve this problem?
FA2-06: This problem is a hypothesis test for the mean of two populations with the following steps: a) determine the hypotheses, b) determine the critical value, c) calculate the Z value using the formula, d) illustrate the result in a bell curve, e) make a decision and draw a conclusion.

Figure 8: Excerpts from Subject FA's Interview in S2

In the employ aspect, the subject meticulously applies the hypothesis testing steps to both problems. For both the one-population and two-population hypothesis tests, the subject demonstrates precision by rechecking the calculation results up to three times to ensure accuracy. In the interpret aspect, the subject shows a strong ability to interpret the results of hypothesis tests. For the one-population hypothesis test, the subject illustrates the results in the form of a bell curve and concludes whether the hypothesis is accepted or rejected. For the two-population hypothesis test, the subject successfully concludes that the productivity of apple orchards in one location is higher than in another based on the calculation results.

From the above analysis, it can be concluded that subjects with high self-efficacy show consistency in their ability to formulate, apply, and interpret statistical problems, even though Problem S2 is slightly more complex. Nevertheless, the subject is able to apply the same steps effectively, demonstrating a strong understanding and high self-efficacy in solving statistical problems.

2. **Subject with Medium Self-Efficacy (Subject IN)**

The subject's ability in the formulate aspect shows a similar pattern when solving Problems S1 and S2. The subject is able to identify important information but lacks depth in developing an appropriate mathematical model. This is evident as the subject struggles to convert the real-world problem in S1 into a suitable mathematical model, as indicated by the response mentioning "just substitute into the formula" without further elaboration. The subject also experiences difficulty converting the S2 problem into a mathematical model, providing similarly brief answers as in S1. In the employ aspect, the subject demonstrates a similar mechanical ability to apply procedures, but there are more errors in S2 related to the choice of the appropriate statistical test.

While solving Problem S2, the subject initially attempted to use the t-test but later realized that the Z-test would be more appropriate. This is evident from the following excerpts from the S2 problem.

P2-07: Why did you use the t-test statistic?
IN2-07: (thinking) I don't know, Ma'am.
P2-08: Is it correct to use the t-test? Why not use the Z-test? Please review the material on this topic.
IN2-08: Okay, Ma'am.
P2-09: Actually, the formula you wrote is for the Z-test, but here it says it's a t-test.
IN2-09: Oh yes, Ma'am, I wrote it incorrectly here.

Figure 9: Excerpts from Subject IN's Interview in S2

The subject shows reliance on the given formula without a clear understanding of the difference between the t-test and the Z-test, leading to mistakes in the initial steps of problem-solving. The evaluation of the results is also conducted using SPSS, similar to S1, without a more in-depth manual evaluation. This is reflected in the subject's interview when solving Problem S2 below.

P2-10: How do you evaluate/correct the solution so that the correct answer is obtained?
IN2-10: The same as before, Ma'am, using the SPSS application.

Figure 10: Excerpts from Subject IN's Interview in S2

Furthermore, in the interpret aspect, the subject is consistent in both problems, but the results lack depth and confidence in drawing conclusions. In S1, the subject can draw basic conclusions based on the hypothesis formulation and critical points but does not show full confidence in the interpretation, as it lacks strong explanations regarding the implications or relevance of the results. This is evident from the following excerpt from the subject's interview when solving Problem S1.

P1-14: What can you interpret from the results you obtained?
IN1-14: The average body weight of residents in Makmur Sentosa Village is > 52 kg.

Figure 11: Excerpts from Subject IN's Interview in S1

From the excerpt above, the subject only provided a basic conclusion without strong explanations regarding the implications or relevance of the results. While solving the S2 problem, the subject shows uncertainty in the interpretation process, such as the initial mistake in using the t-test. Although the subject was able to correct the error, the final interpretation remains limited to general conclusions without a more in-depth discussion of the relevance of the results.

Based on the above findings, it can be concluded that the subject with moderate self-efficacy shows a consistent pattern across the three aspects of mathematical literacy: formulate, employ, and interpret. In the formulate aspect, the subject has a basic understanding but lacks depth in converting problems into mathematical models. In the employ aspect, the subject tends to follow procedures correctly but experiences confusion in selecting the appropriate statistical test. Meanwhile, in the interpret aspect, the subject can draw conclusions but lacks confidence and depth in interpreting the results. Overall, although there is some progress from solving S1 to S2, the subject still requires further development, particularly in the interpret aspect, with more critical reflection and evaluation to enhance mathematical literacy.

3. **Subject with Low Self-Efficacy (Subject AN)**

   In the formulate aspect, the subject understands the context of both S1 and S2 problems in real-world settings and is able to identify key elements such as the mean, variance, standard deviation, and significance level. Subsequently, in the employ aspect, the subject accurately explains the steps for problem-solving, such as formulating the hypotheses, determining the significance level, calculating the test statistics, and comparing the results with critical values. However, the understanding of result interpretation appears to be less in-depth, particularly in identifying potential errors. Additionally, the subject seems to lack depth in the evaluation and refinement of the calculation results.

   Furthermore, in the interpret aspect, for Problem S1, the subject successfully concludes that there is insufficient evidence to reject the null hypothesis. The interpretation regarding public health is correct but lacks further in-depth analysis. For Problem S2, the subject successfully concludes that the productivity of the apple orchard in Kota Batu is higher than in Poncokusumo. The interpretation of the results aligns with the planned analysis and demonstrates a good understanding of data analysis.

From the above discussion, it can be concluded that, in solving Problem S1, the subject demonstrates a good basic understanding in the formulate and employ aspects, but the result interpretation remains less in-depth in the context of practical application. In solving Problem S2, the subject shows better skills in formulation and interpretation, with conclusions consistent with the conducted analysis, although the evaluation process could be improved. These findings suggest that, while the subject has a solid basic understanding of statistics and hypothesis testing, enhancing the depth of evaluation and interpretation could help improve their mathematical literacy skills.

4.2.3 Member Checking Results

To ensure data credibility and enhance the validity of the findings, member checking was conducted by involving the research subjects in verifying the interview transcripts and the interpretations of the data. This process was carried out after the transcription and initial analysis of the subjects' mathematical literacy abilities, based on the indicators of formulate, employ, and interpret, had been completed.

Each subject was given the opportunity to review their interview transcript together with the written interpretation of their statistical problem-solving process. The subjects were asked to confirm the accuracy of the transcripts and to indicate whether the interpretations were consistent with their thoughts, intentions, and experiences during the problem-solving activities.

The member checking process is summarized as follows:

(a) Subject RG (high metacognition): Confirmed that the transcript and the researcher's explanation about the initial error in formulating the hypothesis in S1 and the subsequent correction accurately reflected her thinking process.

(b) Subject IR (moderate metacognition): Agreed that the researcher's description of his confusion in transforming the context into a mathematical model genuinely represented his experience.

(c) Subject FA (high self-efficacy): Agreed with all the transcripts and interpretations, including the description of her thorough calculations and the use of bell curve illustrations.

(d) Subject IN (moderate self-efficacy): Provided a minor correction to one part of the interpretation, which was considered by the researcher-regarding the simplified explanation of her reason for initially choosing the t-test.

(e) Subject AN (low self-efficacy): Did not suggest any corrections and stated that the researcher's description sufficiently captured her thought process during problem solving.

Thus, the results of the member checking indicate that the subjects affirmed the accuracy of the researcher's descriptions, with only minor revision needed for one subject. This strengthens the credibility and trustworthiness of the qualitative findings in this study.

5 Discussion

Mathematical literacy in this study encompasses three main aspects: formulating problems (formulate), applying procedures (employ), and interpreting results (interpret). The results of this study indicate that students with good metacognition demonstrate strong abilities in all aspects of mathematical literacy, with an emphasis on detailed formulation and high confidence in interpreting results. This aligns with previous studies that emphasize the importance of flexibility and accuracy in these three aspects [20]. Meanwhile, students with moderate metacognition experience difficulties in deep reflection, which reflects a lack of in-depth understanding in formulation and interpretation. This finding is consistent with the theory of mathematical literacy, which stresses the need for deep understanding and critical reflection [35].

The mistakes students often make in selecting the appropriate statistical tests reflect their inability to effectively identify the relevant procedures for the given problem. This can be seen as a metacognitive gap, where students fail to plan, monitor, and evaluate the necessary steps in statistical testing. Such errors may not only reflect a lack of metacognitive awareness but also indicate deeper cognitive challenges, such as inferential reasoning errors. According to Schraw and Dennison [40], metacognition involves the ability to plan, monitor, and evaluate the steps taken in problem-solving, and students' failure to engage in these reflective processes can lead to significant decision-making errors in statistical contexts.

This misstep in selecting the correct statistical test might not merely be a result of poor planning or monitoring but also a failure in logical reasoning. Inferential reasoning requires students to accurately assess the relationship between sample data and population assumptions, as discussed by Muncer et al.[58]. When students choose the wrong test, it may reflect a fundamental misunderstanding of these relationships-what could be considered an inferential error rather than solely a metacognitive oversight.

More recent research by Dewi and Saputro [15] further supports the idea that metacognitive strategies are essential for students to navigate complex tasks successfully. However, errors in statistical test selection, such as choosing between a t-test and a z-test, also point to a deeper issue: students' inability to effectively apply inferential logic and metacognitive evaluation in tandem. These mistakes highlight a critical need for instructional strategies that address both metacognitive skills and the logical foundations of statistical reasoning. Teaching methods that integrate metacognitive reflection, feedback, and reasoning practice could prevent such errors and enhance students' ability to select the appropriate tests and interpret their results correctly.

Furthermore, students with high self-efficacy exhibit strong understanding in formulating, employing, and interpreting, showing consistency in applying procedures and interpreting results. This is in line with self-efficacy theory, which states that confidence affects accuracy in solving mathematical tasks [60]. On the other hand, students with moderate and low self-efficacy show differences in the depth of formulation and interpretation of results, in accordance with self-efficacy theory, which indicates that the level of self-confidence influences the quality and depth of problem-solving [12].

According to Bandura [7], self-efficacy influences how individuals regulate and apply their cognitive strategies. Students with high self-efficacy are more confident in selecting and applying effective metacognitive strategies. This strengthens the relationship between self-confidence and reflective ability, as described in Zimmerman's Self-Regulated Learning Model [67]. According to this model, students with high self-efficacy not only exhibit better management of their learning strategies but also engage in more effective self-monitoring and self-evaluation. This continuous cycle of monitoring and adjusting strategies leads to greater mastery of learning tasks, especially those that are more complex and require advanced problem-solving abilities.

Furthermore, Bandura [7] explains that self-efficacy influences an individual's perception of their ability to complete tasks. Students with high self-efficacy are more likely to trust their abilities to choose and apply effective strategies, including metacognitive strategies. This aligns with Zimmerman's theory [67], which states that self-efficacy plays a crucial role in self-regulated learning. Self-regulation involves the interplay of cognitive, motivational, and emotional components, where self-efficacy serves as a key determinant in students' persistence and strategy use. Students with high self-efficacy are better at monitoring and evaluating their performance, thereby enhancing their understanding of more complex problems and enabling them to adapt their approaches as needed.

In the context of mathematical literacy, the ability to formulate problems, apply procedures, and interpret results is often influenced by how well an individual regulates and evaluates their thinking process (metacognition) and their confidence in their ability to complete the task (self-efficacy) [37]. Therefore, subjects with a combination of good metacognition and high self-efficacy perform better in all aspects of mathematical literacy, as they are able to accurately formulate problems, appropriately apply procedures, and confidently interpret results.

As explained by Schraw and Dennison [58], metacognition involves planning, monitoring, and evaluating the thinking process. Therefore, teaching strategies that integrate self-reflection and continuous feedback can enhance students' metacognitive abilities. Research by Dewi and Saputro [15] also shows that students trained in metacognitive-based learning strategies demonstrate improved reflective skills in solving more complex mathematical problems. Based on these findings, the design of mathematics instruction, particularly in statistics, should incorporate activities that enhance students' metacognition. One effective approach is using problem-based learning (PBL), which provides students with opportunities to plan, monitor, and evaluate their solutions. PBL encourages active learning and helps students apply their mathematical knowledge in real-world contexts, fostering a deeper understanding of statistical concepts.

Additionally, teaching strategies that offer positive feedback and opportunities for reflective discussions can further support the development of self-efficacy, helping students build confidence in tackling more complex statistical tasks. This aligns with Bandura's [7] theory on self-efficacy, suggesting that students with high self-efficacy are more likely to engage with challenging tasks and persist through difficulties. Furthermore, implementing formative assessments that provide immediate, constructive feedback can aid in the development of both metacognitive skills and self-efficacy. In this context, reforming the curriculum to focus on activities that encourage self-regulation and reflection will not only improve statistical literacy but also prepare students to approach complex mathematical problems with greater confidence and strategic thinking.

The findings of this study reveal a strong relationship between metacognition, self-efficacy, and mathematical literacy. Students with good metacognition or high self-efficacy tend to exhibit better abilities in all aspects of mathematical literacy, while subjects with lower metacognition and self-efficacy face challenges in formulation, application, and interpretation of results.

6 Conclusions

This study highlights a significant relationship between mathematics literacy and students' levels of metacognition and self-efficacy in solving statistical problems. Students with strong metacognition and high self-efficacy demonstrate superior performance across all three indicators of mathematical literacy: formulating problems, applying procedures, and interpreting results. These students are able to approach statistical problems with deep understanding, flexibility in application, and accuracy in interpretation. In contrast, students with moderate metacognition and lower self-efficacy experience difficulties with critical reflection and deep evaluation, which negatively impacts the quality of their result interpretation.

Enhancing students' metacognition and self-efficacy is crucial for improving overall mathematical literacy, particularly in terms of critical thinking and reflective evaluation. Therefore, it is essential for educational strategies to focus on developing these areas to equip students with the necessary skills to solve complex statistical problems with confidence and accuracy.

Recommendations

Based on the findings, the following recommendations are provided for educators, curriculum developers, and policymakers:

1. For Educators:
   (a) Incorporate metacognitive training and self-regulation techniques into statistical lessons to help students monitor and evaluate their thinking processes effectively.
   (b) Utilize problem-based learning (PBL) to encourage active engagement and foster deeper understanding in students.
   (c) Provide consistent feedback and reflective discussions to build self-efficacy and help students gain confidence in their problem-solving abilities.
2. For Curriculum Developers:
   (a) Design curricula that explicitly include metacognitive strategies and foster self-efficacy in the context of mathematical literacy, particularly in statistical problem-solving.
   (b) Integrate more practical, real-world applications of statistical concepts to enhance students' ability to apply their knowledge flexibly.
3. For Policymakers: Encourage the integration of metacognitive and self-efficacy training within broader educational reforms to ensure that students are better prepared to meet the challenges of higher-order thinking tasks, especially in mathematics and statistics.

Limitations of the Study

While this study provides valuable insights into the role of metacognition and self-efficacy in statistical problem-solving, there are a few limitations to consider:

1. Sample Size

   The study involved a limited number of participants from a single institution, which may not fully represent the diversity of students across different educational contexts. Future studies could benefit from a larger and more diverse sample to improve the generalizability of the findings.
2. Lack of "Low" Metacognition Category

   One significant limitation of this study is the absence of students with "low" metacognition levels in the sample. This limits the ability to compare students with varying levels of metacognitive skills, particularly those with low metacognition. Including a group of students with low metacognition would provide a fuller picture of how students with weaker metacognitive abilities approach statistical problems. Without this comparison, the study risks overlooking potential challenges faced by students with lower metacognitive skills, such as difficulties in problem formulation, application, and result interpretation. Additionally, it makes it difficult to assess the specific impact of weak metacognition on the overall process of statistical problem-solving. Future research could address this by ensuring that students with lower metacognitive skills are included in the sample, allowing for a more nuanced understanding of the relationship between metacognition, self-efficacy, and mathematical literacy.

3. Instrument Validity

   Although the instruments used in this study, such as the Metacognitive Awareness Inventory (MAI) and self-efficacy questionnaire, were validated, further refinement and validation of these tools in different educational settings could improve the reliability of the results. Future studies might benefit from using more diverse instruments or adapting the existing ones to specific educational contexts to enhance the precision and applicability of the findings.

Directions for Future Research

Future research could explore the following areas:

1. Expanded Sample and Diverse Contexts

   Investigating a more extensive and diverse sample across different institutions and educational levels would provide a broader perspective on the relationship between metacognition, self-efficacy, and mathematical literacy. This could help generalize findings to a wider range of educational settings and cultural contexts.

2. Longitudinal Studies

   Conducting longitudinal studies would help assess the long-term effects of metacognitive and self-efficacy interventions on students' mathematical literacy. Understanding the sustained impact of such interventions over time would provide valuable insights into the durability of improvements in students' problem-solving abilities.

3. Intervention Studies

   Future studies could include experimental designs to test the effectiveness of specific metacognitive or self-efficacy interventions on improving students' statistical problem-solving abilities and their overall performance in mathematical literacy. This could involve testing targeted teaching strategies, such as PBL or metacognitive reflection exercises, and evaluating their impact on both metacognitive skills and statistical performance.

By addressing these limitations and exploring these avenues, future research can further contribute to the development of effective strategies for enhancing mathematical literacy and fostering the necessary cognitive and motivational skills in students.

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Appendix A. Metacognitive Awareness Inventory (MAI)

This questionnaire represents the English version of the adapted Metacognitive Awareness Inventory (MAI) originally developed by Schraw and Dennison (1994). It consists of 37 valid items that measure two dimensions of metacognition: metacognitive knowledge and metacognitive experience. The original MAI was translated and contextually adapted into Indonesian for administration to students in the mathematics learning context. Several items were linguistically adjusted to fit the Indonesian educational setting while preserving their original meaning. The full reference for Schraw and Dennison (1994) is listed in the References section.

Instructions: Please read each statement carefully. Put a check mark (✓) in the **True** column if the statement describes you, or in the **False** column if it does not.

No	Statement	True	False
1	I regularly ask myself whether I am achieving the goals I want to achieve.		
2	I consider several options for each problem before making an answer.		
3	I try to use different strategies that have worked successfully in the past.		
4	I push myself to allocate enough time to complete my tasks.		
5	I understand the strengths and weaknesses of my own intelligence.		
6	I anticipate what I really need to learn before I begin a task.		
7	I know how well I am doing when I complete a test or exercise.		
8	I set specific goals before starting a task.		
9	I know what information is most important to learn.		
10	I ask myself whether I have considered all possible options when solving a problem.		
11	I am good at organizing information.		
12	I have specific purposes for each strategy I use.		
13	I learn better when I already know something about the topic.		
14	I know what my teacher wants me to learn.		
15	I am good at remembering information.		
16	I use different learning strategies depending on the situation or condition.		
17	I tell myself if there is an easier way to do things after completing a task.		
18	I monitor how well I am learning.		
19	I regularly review the material to understand important relationships.		
20	I ask myself questions about the material before I start learning.		
21	I consider several ways to solve a problem and choose the best one.		
22	I summarize what I have learned after finishing studying.		
23	I can motivate myself to study when necessary.		
24	I clearly understand which strategies I use while learning.		
25	I benefit from analyzing the strategies I use when studying.		
26	I use my strengths to compensate for my weaknesses.		
27	I make good judgments about how well I understand something.		
28	I automatically discover useful learning strategies.		
29	I regularly pause to check my understanding.		

No	Statement	True	False
30	I know when each strategy I use becomes most effective.		
31	I ask myself how well I am performing.		
32	I ask myself whether I have considered all possible options after completing a problem.		
33	I read instructions carefully before starting a task.		
34	I manage my time well to achieve the best learning outcomes.		
35	I study further if I am interested in the topic.		
36	I ask myself questions about how well I am doing when learning something new.		
37	I ask myself whether I have learned as well as possible when completing a task.		

Appendix B

This questionnaire represents the English version of the adapted Self-Efficacy Scale originally developed by Bandura (1997). It consists of 13 valid items measuring students' confidence in their ability to perform mathematical tasks and overcome academic challenges. All items were validated before use in this study. The instrument was translated and contextually adapted into Indonesian for use in the mathematics learning context, ensuring linguistic and cultural appropriateness for Indonesian students. The full reference for Bandura (1997) is listed in the References section.

Instruction: Please read each statement carefully. Give your response by putting a check mark (✓) in the column that best describes your level of agreement with each statement.

Scale of Response: SS = Strongly Agree, S = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree.

No	Statement	SS	S	N	D	SD
1	I prefer working on challenging mathematical tasks.					
2	I am able to complete mathematical tasks even when they are very difficult.					
3	I do not push myself to work on difficult problems. (*reverse item*)					
4	I can overcome obstacles and challenges to achieve my academic goals.					
5	I continue working on math problems even when I find them difficult.					
6	I tend to avoid problems that have caused me to fail before. (*reverse item*)					
7	I am confident that I can complete mathematical tasks successfully.					
8	I believe I can solve math problems without help from others.					

No	Statement	SS	S	N	D	SD
9	I am not confident that I can do well in school exams. (*reverse item*)					
10	When my grades drop, I believe I can do better in the next semester.					
11	I can use different areas of my knowledge at once to solve math problems.					
12	I am confident that I can handle various activities at the same time.					
13	When I have many activities, I still make time to focus on my math assignments.					