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Unraveling Metacognitive Regulation in Physics: Mapping High School Students' Skills using the Rasch Model

Ihsan Hijria Putra[1], Hera Novia[✉1], Muslim Muslim[1], Rizky Agassy Sihombing[1,2]

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[1]Universitas Pendidikan Indonesia, Indonesia
[2]National Taiwan Normal University, Taiwan

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Abstract

Metacognitive regulation skills are crucial in addressing increasingly complex global challenges. These skills enable individuals to comprehensively solve problems by managing their thinking strategies effectively. This study employs a descriptive approach and utilizes the Metacognitive Awareness Inventory, adapted from Schraw and Dennison's work. The descriptive research involved 53 tenth-grade students from a high school. The primary objective of this study is to map metacognitive regulation and their potential in tackling complex problems. Data analysis integrates Likert-scale results with percentage calculations for each aspect. Additionally, the data were analyzed to determine the reliability of the instrument, identify metacognitive regulation patterns, and map the distribution of students' abilities using the Rasch model. The findings reveal variations in students' metacognitive regulation achievements: Planning 82%, Information Management Strategies 73%, Comprehension Monitoring 77%, Debugging Strategies 82%, and Evaluation 92%. These indicate that students' metacognitive regulation still require further development like Information Management Strategies. The conclusion of this research is students' metacognitive regulation shows variation across domains and it has significant potential in helping to solve complex problems. This study underscores the importance of designing targeted instructional strategies to enhance students' metacognitive regulation skills, ensuring they are better equipped to handle complex learning challenges.

How to Cite

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✉ Correspondence Author:
E-mail: heranovia@upi.edu

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INTRODUCTION

Metacognitive regulation is a crucial aspect of students' cognitive development, particularly in the context of problem-solving. This process refers to the ability to control and monitor one's thinking, learning, and problem-solving activities. As students encounter complex, interdisciplinary problems, the application of metacognitive regulation becomes even more critical (Arianto & Hanif, 2024; Olmo-Muñoz et al., 2024; Zepeda & Nokes-Malasch, 2023). These types of problems often require students to integrate knowledge across different subject areas, employ critical thinking, and navigate challenges that may not have a straightforward solution. The role of metacognitive regulation in this context is to support students in managing their thinking processes, thus enabling them to approach such challenges more effectively (Geng et al., 2025; Popandopulo et al., 2023; Wang et al., 2024).

Metacognition, as a broader concept, includes both the awareness of one's cognitive processes and the strategies to control them (Cakiroglu & Betul, 2023). According to ElSayad (2024), Jiang et al., (2023) and Srivastava (2024), cognitive regulation within metacognition involves a series of activities that help individuals guide their learning, including planning, monitoring, and evaluating their cognitive processes. It is the intentional application of these activities that leads to better problem-solving outcomes. In the process of solving complex problems, students who are able to regulate their thinking are better at selecting appropriate strategies, adjusting their approach when necessary, and ensuring that their solutions are well-founded (Nold, 2017; Rivas et al., 2022). This deepens their understanding of the problem and allows them to arrive at more effective and accurate solutions.

Numerous studies emphasize the importance of metacognitive regulation in learning and problem-solving. For example, Sabaliauskas et al., (2025) and Stanton et al., (2021) stress that metacognitive regulation helps students monitor their progress, adjust their strategies when they encounter obstacles, and reflect on the results of their efforts. This reflective process encourages a more comprehensive understanding of the problem at hand, which is necessary when dealing with complex issues that span multiple disciplines (Chan & Lee, 2021; Daff et al., 2024; Muslim et al., 2024; Sheppik, 2024). In contrast, students who lack metacognitive awareness may struggle to recognize when they need to adjust their strategies, leading to ineffective solutions and incomplete understanding (Biwer et al., 2020; Molin et al., 2020; Rea et al., 2022).

Despite the critical role that metacognitive regulation plays in problem-solving, many students exhibit weaknesses in this area. Research by Cervin-Ellqvist et al., (2021) and Chardonnens (2025) reveals that students often fail to engage in metacognitive processes during their learning. This can stem from a variety of factors, including a lack of awareness of the importance of metacognition, insufficient guidance in developing these skills, or an overreliance on passive learning strategies. Students may struggle with tasks that require deep thinking and strategic problem-solving. For example, they may not plan their learning effectively, fail to assess their understanding throughout the process, or neglect to adjust their approach when faced with difficulties. This lack of engagement with metacognitive regulation can lead to poor academic performance and a limited ability to solve complex problems (Halmo et al., 2023; Narengaowa & Tungalag, 2024).

The findings from Abdelrahman (2020), Lobczowski et al., (2021) and Rajcoomar et al. (2024) highlight that students' metacognitive regulation is often underdeveloped. They may struggle to connect prior knowledge with new information, lack strategies for evaluating their own understanding, or be unable to plan their learning effectively. These students often experience challenges in their academic work and demonstrate lower achievement levels. The ability to connect new information with existing knowledge is particularly important in solving interdisciplinary problems, where students need to synthesize information multiple sources and apply it in novel ways. Without effective metacognitive regulation, students may fail to make these connections, resulting in incomplete or inaccurate solutions.

Given the importance of metacognitive regulation in enhancing problem-solving abilities, there is a clear need for educational interventions that focus on improving these skills. This includes teaching students how to plan their learning, monitor their progress, and reflect on their strategies. By fostering metacognitive awareness, educators can help students develop the skills necessary for solving complex, interdisciplinary problems. This can lead to improved academic performance and better overall problem-solving outcomes.

The researcher is therefore interested in examining the current state of students' metacognitive regulation and exploring its potential role in addressing complex issues. Urgency of this research stems from increasing complexity of real-world problems that require interdisciplinary knowledge, critical thinking, and strategic problem-solving. Many students struggle with metacognitive regulation, leading to ineffective learning strategies, incomplete understanding, and lower academic performance. While metacognition has been widely studied, there is research gap in understanding how students specifically apply metacognitive regulation in complex problem-solving contexts. Existing studies often focus on general learning processes without providing concrete strategies for integrating metacognitive regulation into interdisciplinary problem-solving. Additionally, prior research lacks a detailed analysis of students' metacognitive regulation patterns using robust methodologies such as Rasch model. Novelty of this research lies in specific focus on metacognitive regulation within complex problem-solving situations, combining quantitative and qualitative approaches to provide deeper insights. By identifying instructional strategies that enhance metacognitive regulation, this study aims to bridge gap between theoretical knowledge and practical application, ultimately equipping students with essential cognitive tools to navigate and solve complex challenges effectively.

Specifically, the study aims to investigate how metacognitive regulation can be developed and applied to improve students' problem-solving skills. By gaining insights into students' metacognitive processes, it will be possible to design more effective teaching strategies and learning environments that support the development of these critical skills. Ultimately, this research will contribute to the broader goal of equipping students with the cognitive tools they need to navigate and solve complex problems in various disciplines.

METHOD

Research Design

This research employs a descriptive research method. According to Rukajat (2018), descriptive research aims to realistically, factually, and contemporarily depict phenomena. The study involves systematically creating descriptions, representations, or depictions of facts, characteristics, and the relationships between the phenomena being investigated. This method is suitable for understanding students' metacognitive regulation and its potential in solving complex problems.

Participant

The sample used in this study consists of 53 participants who were selected through simple random sampling. The sampling process was carried out with primary goal of gathering comprehensive and representative information regarding metacognitive regulation within student population that is the focus of this research. By utilizing simple random sampling, each member of the population had an equal chance of being included in the study, ensuring that the sample reflects the diversity and characteristics of the larger population. This approach helps minimize bias and provides a more accurate picture of the students' metacognitive regulation skills, allowing the findings to be generalized to the broader group of students. The process of selecting participants was designed to ensure that the sample was both representative and suitable for investigating the research questions related to students' metacognitive processes and their ability to regulate their thinking when faced with complex problems. By focusing on a specific sample of 53 students, the study aimed to collect detailed and relevant data to understand the various aspects of metacognitive regulation and its potential in addressing the challenges students encounter during learning.

Research Instruments

Data collection in this study was conducted using the Metacognitive Awareness Inventory (MAI) questionnaire developed by Schraw & Dennison, which is based on a Likert scale. This scale provides a structured framework for students to express their perspectives on metacognitive regulation. The questionnaire allows for the systematic collection of responses to analyze various domains of metacognitive regulation among students. The questionnaire is divided into five domains, as outlined in Table 1.

Table 1. Domains of Metacognitive Regulation

Domains	Operational Description	Statements
Planning	Planning, goal setting, and allocating resources prior to learning	7
Information management strategy	Skills and strategy sequences to process information more efficiently (e.g., organizing, elaborating, summarizing, selective focusing)	10
Comprehension monitoring	Assessment of one's learning or strategy use	7
Debugging strategy	Strategies to correct comprehension and performance errors	5
Evaluation	Analysis performance and strategy effectiveness after learning	6

(Schraw & Dennison, 1994)

Table 1 presents the items of the questionnaire used to assess each domain. The domains of metacognitive regulation consist of (1) Planning, (2) Information Management Strategies, (3) Comprehension Monitoring, (4) Debugging Strategies, and (5) Evaluation which consists of a total of 35 statements.

Data Analysis

The questionnaire was administered through Google Forms, which contained 35 statements using a 5-point Likert scale ranging from Strongly Disagree to Strongly Agree. This format allowed for systematic gathering of students' responses regarding their metacognitive regulation. The 5-point scale provided a structured way for students to express the extent to which they agreed or disagreed with each statement, offering valuable insights into their metacognitive awareness. Table 2 presents the alternative assessment options used for evaluating students' responses to questionnaire items, further clarifying rating system for each domain of metacognitive regulation.

Table 2. Likert scale for assessment

Alternative Answer	Score
Very Agree	5
Agree	4
Undecided	3
Disagree	2
Very Disagree	1

(Riduwan, 2015)

Then, the percentage values for each statement item were determined using the following formula (Purwanto, 2002):

$$N = \frac{R}{SM} \text{ x } 100\%$$

Description:

N = Value

R = Raw score obtained by the teacher

SM = Ideal maximum score

Next, the obtained score is converted into a percentage and categorized into the domains of metacognitive regulation, as shown in Table 3.

Table 3. Value Interpretation

Value interval (%)	Interpretation
81 - 100	Very Good
61 - 80	Good
41 - 60	Enough
21 - 40	Less
0 - 20	Very Less

The use of the Likert scale provides a consistent framework for measuring respondents' attitudes, while the random sampling method ensures a representative sample of tenth-grade students. Additionally, the systematic classification of data into predefined categories facilitates a comprehensive analysis of metacognitive regulation.

RESULT AND DISCUSSION

Students' Self-Regulated Learning Profile in Physics Learning

After the MAI questionnaire was distributed and completed by the students, the condition of students' metacognitive regulation was obtained, consisting of five domains as shown in Figure 1.

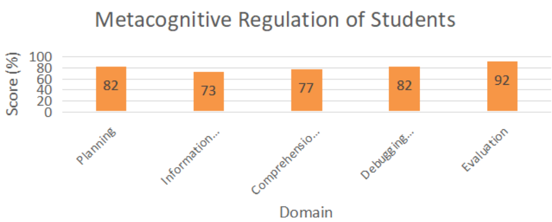

Figure 1. Metacognitive Regulation of Students

The results were classified based on each domain of metacognitive regulation, with the Planning domain scoring 82%, Information Management Strategies 73%, Comprehension Monitoring 77%, Debugging Strategies 82%, and Evaluation 92%. According to Table 3, the Planning domain falls into the "Very Good" category. This indicates that students are able to set goals, choose strategies, and allocate resources effectively (de Jesus, 2021). According to Zhang et al. (2024), the Planning domain in metacognitive regulation is fundamentally related to addressing complex issues through an individual's ability to build a systematic and strategic approach. In solving complex problems, planning initiates goal-directed behavior and enhances the quality of interactions in the problem-solving process. Planning enables individuals to transform complexity into manageable cognitive structures by anticipating, identifying resources, and designing adaptive problem-solving strategies. When faced with complex problems, the Planning domain acts as a cognitive mechanism that helps individuals perform in-depth analysis, map the relationships between problem components, and develop a systematic approach. This process involves breaking down complex problems into simpler components, considering various scenarios, and designing potential interventions.

The Information Management Strategies domain received a score of 73%, which falls into the "Good" category. This shows that students are able to select, organize, and synthesize information from various sources systematically and critically. Effective metacognitive regulation through information management strategies leads to improved problem-solving abilities. This is particularly evident in collaborative and dynamic environments, where joint regulation and adaptability are key (Astutik & Wusqo, 2023; Raes et al., 2016; Terneusen et al., 2024). According to Schraw and Dennison, the Information Management Strategies domain in metacognitive regulation is essentially concerned with addressing complex issues through mechanisms to capture, process, and transform information strategically. When facing complex issues, information management strategies serve as cognitive mechanisms that help individuals filter relevant information, identify hidden patterns, and construct a comprehensive understanding. This process involves the ability to evaluate the credibility of sources, integrate diverse perspectives, and create accurate and profound cognitive representations of the issues at hand.

The Comprehension Monitoring domain scored 77%, which is categorized as "Good." This means that students actively monitor their cognitive processes, identify gaps in understanding, and make strategic adjustments during problem-solving. Effective comprehension monitoring can significantly enhance problem-solving by enabling students to recognize when they do not understand an issue and adjust their approach (Noushad et al., 2024; Zargar et al., 2020). According to Schraw and Dennison (2014) and Loon & Roebers (2024), the Comprehension Monitoring domain in metacognitive regulation is crucial for addressing complex problems through continuous mechanisms to evaluate and build understanding. When faced with complex issues, comprehension monitoring acts as a reflective mechanism that helps individuals develop deep metacognitive awareness. This process involves identifying inconsistencies, evaluating the accuracy of understanding, and continuously correcting the frameworks used in addressing the problem.

The Debugging Strategies domain received a score of 82%, which falls into the "Very Good" category. It indicates that a student possesses a highly developed ability to recognize, evaluate, and resolve errors or obstacles in their thinking and learning processes. In other words, they can effectively identify issues in their understanding, explore alternative strategies, and adjust their learning approaches to achieve optimal outcomes. This reflects a strong metacognitive awareness and the ability to manage their cognitive processes independently and reflectively. These strategies are essential for identifying and correcting mistakes in understanding or problem-solving approaches (Janssen & Lazonder, 2024; Sugiharto et al., 2017). According to Schraw and Dennison (2014) and Chen (2020), the Debugging Strategies domain in metacognitive regulation is strategically related to complex problems through cognitive mechanisms for correction, modification, and continuous improvement. Debugging strategies are vital in solving complex problems as they allow individuals to adjust their cognitive tactics and strategies to fit the task at hand. This adaptability is especially important in domains where problems are poorly defined and require iterative refinement. When faced with complex problems, debugging strategies act as a cognitive adaptation mechanism that helps individuals turn limitations or failures into learning opportunities. This process involves deep reflection, exploring alternative approaches, and building more comprehensive and innovative solutions.

The Evaluation domain received a score of 92%, which is categorized as "Very Good." This shows that students are able to critically assess the entire cognitive process, analyze the effectiveness of the strategies used, and develop a deep understanding of the quality of problem-solving outcomes. According to Schraw and Dennison, the Evaluation domain in metacognitive regulation is fundamentally related to complex problems through systematic and reflective assessment mechanisms. Effective metacognitive regulation enables individuals to identify and correct errors, leading to better problem-solving outcomes (de Jesus, 2021; Güner & Erbay, 2021; Fleur et al., 2021). When faced with complex problems, evaluation acts as a metacognitive mechanism that helps individuals build comprehensive meaning from their thinking process and outcomes (Çini et al, 2023; Jia et al., 2019; Negi et al., 2022). This process involves identifying the strengths and weaknesses of the approaches used, considering the consequences of the chosen strategies, and generating reflective insights that facilitate the development of intellectual capacity.

Analysis of the Metacognitive Awareness Inventory Instrument

The analysis of the metacognitive awareness inventory can be seen in Figure 2 and Figure 3.

```
     SUMMARY OF 53 MEASURED (EXTREME AND NON-EXTREME) Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      10.5      35.0       -1.31     .56                                |
| S.D.       7.5        .0        1.59     .38                                |
| MAX.      31.0      35.0        2.28    1.82                                |
| MIN.        .0      35.0       -5.01     .36       .79    -.8    .47   -1.0 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .68 TRUE SD    1.43  SEPARATION  2.12  Person RELIABILITY  .82 |
|MODEL RMSE    .67 TRUE SD    1.44  SEPARATION  2.13  Person RELIABILITY  .82 |
| S.E. OF Person MEAN = .22                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .94
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .90
```

Figure 2. Summary of Measured Person Testing

```
     SUMMARY OF 35 MEASURED (NON-EXTREME) Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE     COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      15.9      53.0         .00     .37      1.00     .1    .92    -.1 |
| S.D.       6.1        .0         .80     .05       .19    1.1    .29    1.0 |
| MAX.      30.0      53.0        2.00     .56      1.35    2.5   1.53    2.2 |
| MIN.       4.0      53.0       -1.61     .33       .64   -2.2    .39   -1.9 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .38 TRUE SD     .70  SEPARATION  1.81  Item   RELIABILITY  .77 |
|MODEL RMSE    .37 TRUE SD     .70  SEPARATION  1.91  Item   RELIABILITY  .78 |
| S.E. OF Item MEAN = .14                                                     |
-------------------------------------------------------------------------------
UMEAN=.0000 USCALE=1.0000
Item RAW SCORE-TO-MEASURE CORRELATION = -.99
1715 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 1656.86 with 1632 d.f. p=.3283
Global Root-Mean-Square Residual (excluding extreme scores): .4020
Capped Binomial Deviance = .1943 for 1855.0 dichotomous observations
```

Figure 3. Summary of Item Testing

The analysis results show that the Cronbach's Alpha value, which represents students' interaction with the comprehension test instrument as a whole, reaches 0.90, which falls into the very good category. This indicates that the instrument has a high level of reliability, meaning that the test results can be trusted to consistently measure students' comprehension. Additionally, the person reliability value of 0.82 indicates that the consistency of students' responses is categorized as good, meaning that students with the same level of understanding tend to provide similar answers.

This reflects that the test instrument effectively measures students' comprehension and is not influenced by external factors that could cause inconsistent responses. Meanwhile, the item reliability value of 0.77 suggests that the quality of the test items in the comprehension instrument is also classified as good. This means that the test questions exhibit a sufficient level of consistency in distinguishing different levels of student comprehension. Therefore, overall, these results demonstrate that the test instrument used has a high level of reliability in terms of overall reliability, response consistency, and item quality, making it a valid and reliable tool for assessing students' comprehension (Sumintono & Widhiarso, 2015).

Analysis of Students Metacognitive Regulation in Physics Learning Using the Metacognitve Awareness Inventory Questionnaire

The test instrument items are classified into four categories: very easy, easy, difficult, and very difficult. The difficulty level of each test item is determined based on the JMLE MEASURE value. The distribution of item difficulty levels can be further analyzed through the mapping presented in Figure 4.

```
                      Person - MAP - Item
                          <more>|<rare>
 3                              +
                                |
                                |
                                |
                                |
                                |
                           01L  |
                                |
 2                              +  Q14
                                |
                                |  Q8
                                |T
                           50L T|
                           51P  |
                                |  Q23
                                |
 1                              +
                           07P  |  Q12    Q15    Q16
                                |S Q22
                           31P  |
                                |  Q20    Q21
                           12P  |  Q17    Q34
                               S|  Q10    Q28    Q4
                           04P  |  Q11
 0                    44P  46L +M  Q9
                      33L  37P  |  Q1     Q18    Q35
                           43P  |  Q24    Q30    Q32
                      05L  40P  |  Q33
                 39P  42P  47P  |  Q2     Q3
                      02L  20L  |  Q19    Q27    Q6     Q7
                 09L  24L  45L  |S Q5
                      06L  48P  |  Q31
-1      10P  14L  15L  26L M+  Q13    Q26
                                |  Q25
                           25P  |
        03L  08L  16P  19P  |
                           36P  |
                                |T Q29
                           32L  |
                                |
-2      11P  30L  35P  52P  +
                                |
        29P  38P  49P  53P S|
                                |
                                |
                           13L  |
                                |
                                |
-3 17L  21P  23L  27P  34P  +
                                |
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                               T|
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                                |
                                |
-4      18P  22L  28P  41P  +
                          <less>|<frequ>
```

Figure 4. Mapping of Test Instrument Difficulty Levels

In Figure 4, the right side of the dashed line represents the test items, while the left side illustrates the students' ability to answer these items. A positive measure value indicates that a particular test item is relatively difficult, meaning that only students with higher ability levels are more likely to answer it correctly. The most difficult questions according to students are Q8, Q12, Q14, Q15, Q16, and Q22, Q23 conversely, a negative measure value suggests that the test item is easier, implying that a larger number of students, including those with lower ability levels, can successfully respond to it. Therefore, the higher the measure value assigned to a test item, the greater the level of difficulty it presents. This measurement helps in understanding the distribution of item difficulties in relation to student abilities, providing valuable insights into how well the test differentiates between students of varying skill levels.

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
1	31	35	2.28	.55	.97	.1	.77	-.2	.33	.26	88.6	88.5	01L
50	28	35	1.55	.45	.99	.0	1.18	.6	.27	.31	85.7	80.8	50L
51	27	35	1.37	.43	1.10	.5	1.55	1.6	.13	.32	77.1	78.4	51P
7	24	35	.87	.39	1.03	.2	.99	.0	.32	.34	71.4	71.6	07P
31	22	35	.59	.37	.96	-.2	.93	-.3	.40	.35	71.4	68.3	31P
12	20	35	.31	.37	.98	-.1	.93	-.4	.39	.35	65.7	65.9	12P
4	19	35	.18	.36	1.11	.9	1.11	.8	.23	.35	60.0	65.3	04P
44	18	35	.05	.36	1.19	1.6	1.30	2.0	.09	.35	60.0	64.8	44P
46	18	35	.05	.36	.99	.0	.96	-.2	.37	.35	65.7	64.8	46L
33	17	35	-.08	.36	1.28	2.3	1.48	2.9	-.03	.35	54.3	64.5	33L
37	17	35	-.08	.36	.91	-.8	.87	-.9	.47	.35	71.4	64.5	37P
43	16	35	-.21	.36	1.01	.1	.98	.0	.34	.34	60.0	64.6	43P
5	15	35	-.34	.36	1.15	1.3	1.12	.8	.18	.34	57.1	65.2	05L
40	15	35	-.34	.36	.94	-.5	.90	-.6	.42	.34	68.6	65.2	40P
39	14	35	-.47	.37	1.00	.0	1.08	.5	.32	.33	68.6	65.9	39P
42	14	35	-.47	.37	1.18	1.4	1.22	1.2	.11	.33	57.1	65.9	42P
47	14	35	-.47	.37	.98	-.1	.96	-.2	.36	.33	62.9	65.9	47P
2	13	35	-.61	.37	1.04	.3	.98	.0	.30	.33	62.9	66.8	02L
20	13	35	-.61	.37	1.15	1.2	1.27	1.3	.13	.33	57.1	66.8	20L
9	12	35	-.75	.38	1.04	.3	.96	-.1	.30	.32	60.0	68.3	09L
24	12	35	-.75	.38	1.04	.3	1.21	1.0	.23	.32	65.7	68.3	24L
45	12	35	-.75	.38	1.13	.9	1.07	.4	.19	.32	54.3	68.3	45L
6	11	35	-.89	.38	.96	-.2	.91	-.3	.37	.31	68.6	70.1	06L
48	11	35	-.89	.38	.98	-.1	.91	-.3	.35	.31	68.6	70.1	48P
10	10	35	-1.04	.39	1.05	.4	1.00	.1	.25	.30	71.4	72.3	10P
14	10	35	-1.04	.39	.96	-.1	.94	-.2	.35	.30	71.4	72.3	14L
15	10	35	-1.04	.39	1.02	.2	.92	-.2	.31	.30	71.4	72.3	15L
26	10	35	-1.04	.39	1.14	.8	1.08	.4	.16	.30	65.7	72.3	26L
25	9	35	-1.20	.41	.92	-.4	.88	-.3	.39	.29	77.1	74.8	25P
3	8	35	-1.37	.42	.96	-.1	.80	-.5	.37	.28	74.3	77.4	03L
8	8	35	-1.37	.42	1.02	.2	1.00	.1	.25	.28	74.3	77.4	08L
16	8	35	-1.37	.42	.88	-.5	.85	-.4	.42	.28	80.0	77.4	16P
19	8	35	-1.37	.42	1.05	.3	1.01	.1	.23	.28	74.3	77.4	19P
36	7	35	-1.55	.44	.96	-.1	.80	-.4	.35	.27	77.1	80.0	36P
32	6	35	-1.76	.46	.81	-.6	.82	-.3	.45	.25	82.9	82.8	32L
11	5	35	-1.99	.50	.98	.1	.97	.1	.25	.23	85.7	85.6	11P
30	5	35	-1.99	.50	.83	-.4	.56	-.9	.48	.23	85.7	85.6	30L
35	5	35	-1.99	.50	.80	-.6	.54	-1.0	.51	.23	85.7	85.6	35P
52	5	35	-1.99	.50	.86	-.3	.60	-.8	.45	.23	85.7	85.6	52P
29	4	35	-2.26	.54	.98	.1	.72	-.3	.28	.21	88.6	88.5	29P
38	4	35	-2.26	.54	.94	.0	.67	-.4	.33	.21	88.6	88.5	38P
49	4	35	-2.26	.54	.79	-.4	.48	-.9	.50	.21	88.6	88.5	49P
53	4	35	-2.26	.54	1.06	.3	1.10	.4	.12	.21	88.6	88.5	53P
13	3	35	-2.60	.61	.83	-.2	.47	-.7	.44	.19	91.4	91.4	13L
17	2	35	-3.05	.74	1.00	.2	.72	.0	.19	.16	94.3	94.2	17L
21	2	35	-3.05	.74	.88	.0	.49	-.4	.35	.16	94.3	94.2	21P
23	2	35	-3.05	.74	1.01	.2	.90	.2	.15	.16	94.3	94.2	23L
27	2	35	-3.05	.74	.91	.1	.47	-.5	.33	.16	94.3	94.2	27P
34	2	35	-3.05	.74	.95	.1	.59	-.2	.27	.16	94.3	94.2	34P
18	0	35	-5.01	1.82	MINIMUM MEASURE				.00	.00	100.0	100.0	18P
22	0	35	-5.01	1.82	MINIMUM MEASURE				.00	.00	100.0	100.0	22L
28	0	35	-5.01	1.82	MINIMUM MEASURE				.00	.00	100.0	100.0	28P
41	0	35	-5.01	1.82	MINIMUM MEASURE				.00	.00	100.0	100.0	41P
MEAN	10.5	35.0	-1.31	.56	.99	.2	.92	.0			74.8	76.4	
S.D.	7.5	.0	1.59	.38	.10	.6	.24	.8			12.2	10.2	

Figure 5. Logit of each student based on the output table of Pearson Measure

Person STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
51	27	35	1.37	.43	1.10	.5	1.55	1.6	A .13	.32	77.1	78.4	51P
33	17	35	-.08	.36	1.28	2.3	1.48	2.9	B-.03	.35	54.3	64.5	33L
44	18	35	.05	.36	1.19	1.6	1.30	2.0	C .09	.35	60.0	64.8	44P
20	13	35	-.61	.37	1.15	1.2	1.27	1.3	D .13	.33	57.1	66.8	20L
42	14	35	-.47	.37	1.18	1.4	1.22	1.2	E .11	.33	57.1	65.9	42P
24	12	35	-.75	.38	1.04	.3	1.21	1.0	F .23	.32	65.7	68.3	24L
50	28	35	1.55	.45	.99	.0	1.18	.6	G .27	.31	85.7	80.8	50L
5	15	35	-.34	.36	1.15	1.3	1.12	.8	H .18	.34	57.1	65.2	05L
26	10	35	-1.04	.39	1.14	.8	1.08	.4	I .16	.30	65.7	72.3	26L
45	12	35	-.75	.38	1.13	.9	1.07	.4	J .19	.32	54.3	68.3	45L
4	19	35	.18	.36	1.11	.9	1.11	.8	K .23	.35	60.0	65.3	04P
53	4	35	-2.26	.54	1.06	.3	1.10	.4	L .12	.21	88.6	88.5	53P
39	14	35	-.47	.37	1.00	.0	1.08	.5	M .32	.33	68.6	65.9	39P
19	8	35	-1.37	.42	1.05	.3	1.01	.1	N .23	.28	74.3	77.4	19P
10	10	35	-1.04	.39	1.05	.4	1.00	.1	O .25	.30	71.4	72.3	10P
2	13	35	-.61	.37	1.04	.3	.98	.0	P .30	.33	62.9	66.8	02L
9	12	35	-.75	.38	1.04	.3	.96	-.1	Q .30	.32	60.0	68.3	09L
7	24	35	.87	.39	1.03	.2	.99	.0	R .32	.34	71.4	71.6	07P
8	8	35	-1.37	.42	1.02	.2	1.00	.1	S .25	.28	74.3	77.4	08L
15	10	35	-1.04	.39	1.02	.2	.92	-.2	T .31	.30	71.4	72.3	15L
23	2	35	-3.05	.74	1.01	.2	.90	.2	U .15	.16	94.3	94.2	23L
43	16	35	-.21	.36	1.01	.1	.98	.0	V .34	.34	60.0	64.6	43P
17	2	35	-3.05	.74	1.00	.2	.72	.0	W .19	.16	94.3	94.2	17L
46	18	35	.05	.36	.99	.0	.96	-.2	X .37	.35	65.7	64.8	46L
11	5	35	-1.99	.50	.98	.1	.97	.1	Y .25	.23	85.7	85.6	11P
47	14	35	-.47	.37	.98	-.1	.96	-.2	x .36	.33	62.9	65.9	47P
29	4	35	-2.26	.54	.98	.1	.72	-.3	w .28	.21	88.6	88.5	29P
48	11	35	-.89	.38	.98	-.1	.91	-.3	v .35	.31	68.6	70.1	48P
12	20	35	.31	.37	.98	-.1	.93	-.4	u .39	.35	65.7	65.9	12P
1	31	35	2.28	.55	.97	.1	.77	-.2	t .33	.26	88.6	88.5	01L
14	10	35	-1.04	.39	.96	-.1	.94	-.2	s .35	.30	71.4	72.3	14L
36	7	35	-1.55	.44	.96	-.1	.80	-.4	r .35	.27	77.1	80.0	36P
31	22	35	.59	.37	.96	-.2	.93	-.3	q .40	.35	71.4	68.3	31P
3	8	35	-1.37	.42	.96	-.1	.80	-.5	p .37	.28	74.3	77.4	03L
6	11	35	-.89	.38	.96	-.2	.91	-.3	o .37	.31	68.6	70.1	06L
34	2	35	-3.05	.74	.95	.1	.59	-.2	n .27	.16	94.3	94.2	34P
38	4	35	-2.26	.54	.94	.0	.67	-.4	m .33	.21	88.6	88.5	38P
40	15	35	-.34	.36	.94	-.5	.90	-.6	l .42	.34	68.6	65.2	40P
25	9	35	-1.20	.41	.92	-.4	.88	-.3	k .39	.29	77.1	74.8	25P
27	2	35	-3.05	.74	.91	.1	.47	-.5	j .33	.16	94.3	94.2	27P
37	17	35	-.08	.36	.91	-.8	.87	-.9	i .47	.35	71.4	64.5	37P
16	8	35	-1.37	.42	.88	-.5	.85	-.4	h .42	.28	80.0	77.4	16P
21	2	35	-3.05	.74	.88	.0	.49	-.4	g .35	.16	94.3	94.2	21P
52	5	35	-1.99	.50	.86	-.3	.60	-.8	f .45	.23	85.7	85.6	52P
30	5	35	-1.99	.50	.83	-.4	.56	-.9	e .48	.23	85.7	85.6	30L
13	3	35	-2.60	.61	.83	-.2	.47	-.7	d .44	.19	91.4	91.4	13L
32	6	35	-1.76	.46	.81	-.6	.82	-.3	c .45	.25	82.9	82.8	32L
35	5	35	-1.99	.50	.80	-.6	.54	-1.0	b .51	.23	85.7	85.6	35P
49	4	35	-2.26	.54	.79	-.4	.48	-.9	a .50	.21	88.6	88.5	49P
MEAN	10.5	35.0	-1.31	.56	.99	.2	.92	.0			74.8	76.4	
S.D.	7.5	.0	1.59	.38	.10	.6	.24	.8			12.2	10.2	

Figure 6. Students Response Fit

Based on Figure 5, the total score represents the raw score obtained by each respondent, which reflects the number of correct answers they provided. The respondents who answered the most questions correctly were Respondent 01L and Respondent 50L, achieving scores of 31 and 28, respectively. This indicates that these two respondents demonstrated the highest level of accuracy in answering the test items compared to their peers. The total score serves as an important indicator of individual performance, providing insight into the respondents' proficiency in relation to the assessed material. Furthermore, analyzing the distribution of total scores across all respondents can help identify patterns in student performance, such as whether certain questions were more challenging for the majority or if specific respondents consistently outperformed others. This data is valuable for evaluating the overall effectiveness of the test in distinguishing different levels of student ability.

Students' Response Fit to the Rasch Model

The student response fit data is analyzed to determine whether there are any respondents classified as outliers or not fitting the expected response pattern. The results are presented in Figure 6.

Based on Figure 6, it can be observed that Respondent 51P is classified as an outlier or does not fit the expected response pattern according to the Rasch analysis. In the context of Rasch measurement, a respondent is considered misfitting when their responses deviate significantly from the model's predictions. This could indicate inconsistencies in their answer patterns, which may result from various factors such as guessing, misunderstanding the questions, or other external influences that affect their performance.

Rasch analysis evaluates response fit through statistical indicators such as infit and outfit mean-square values. If a respondent's infit or outfit values are excessively high, it suggests unpredictable or erratic responses, meaning their performance does not align with the expected difficulty hierarchy of the test items. Conversely, extremely low values may indicate overly predictable responses, potentially due to response bias or lack of engagement.

In this case, Respondent 51P's misfit status implies that their responses do not conform well to the model, making their data less reliable for measuring ability within the Rasch framework. Further investigation may be needed to determine whether this misfit arises from random guessing, test anxiety, or other factors affecting their performance. Identifying misfitting respondents is crucial in Rasch analysis, as it helps ensure the validity and reliability of the assessment tool in accurately measuring student abilities.

Metacognitive regulation can be developed through targeted interventions that promote planning, monitoring, and evaluating of understanding during problem-solving tasks. This approach helps students enhance their metacognitive monitoring, leading to improved problem-solving skills. By integrating metacognitive strategies with cognitive strategies, students can better navigate complex problems and enhance their overall academic performance (Santiago et al., 2024). Additionally, course activities in blended learning environments, such as strategy instruction and reflective journals, significantly enhance students' metacognitive regulation, particularly in monitoring and evaluation (Zuo et al., 2024).

This study emphasizes the importance of metacognitive regulation in learning and problem-solving. Pre-service teachers with strong metacognitive skills are better equipped to identify, reflect on, and correct their misconceptions about scientific concepts. The study also highlights that targeted instructional strategies can enhance metacognitive regulation. Therefore, integrating these strategies into teacher education programs is essential to help pre-service teachers recognize and address misconceptions before conveying them to students. Furthermore, utilizing the Metacognitive Awareness Inventory (MAI) enables educators to assess pre-service teachers' metacognitive skills and design interventions tailored to their specific needs.

CONCLUSION

The condition of students' metacognitive regulation shows variation across different domains. The Planning aspect reached 82%, Information Management Strategies 73%, Comprehension Monitoring 77%, Problem-Solving Strategies 82%, and Evaluation 92% out of a maximum score of 100%. Metacognitive regulation has significant potential in aiding the resolution of complex issues or problems. However, the research findings underscore the importance of developing targeted instructional strategies specifically designed to enhance students' metacognitive regulation skills, thereby equipping them to tackle complex challenges in learning. These findings suggest that while students exhibit varying levels of metacognitive regulation across different areas, there is considerable room for improvement. For example, the relatively lower score in Information management strategies (73%) highlights a specific area where students may struggle to effectively apply metacognitive strategies in more complex information management scenarios. Therefore, the results emphasize the need for targeted interventions that address the specific domains of metacognitive regulation where students are currently underperforming, such as Information Management Strategies domain.

Such interventions would help students develop the necessary skills to plan, monitor, evaluate, and adjust their cognitive processes, ultimately improving their ability to solve complex problems. By incorporating metacognitive regulation training into learning activities, educators can help students develop a more reflective and strategic approach to problem-solving, ensuring that they are better equipped to handle interdisciplinary and multifaceted issues. This approach will foster not only improved academic performance but also long-term success in addressing complex challenges across various fields of study.

This study has several limitations, including reliance on self-reported data, which may not fully reflect actual metacognitive skills, and a limited sample of high school students in West Java, restricting generalizability. Its cross-sectional design captures only a single point in time, and the focus on quantitative methods may lack deeper insights into students' thought processes.

Future research should adopt a mixed-methods approach, incorporating qualitative data like interviews to better understand metacognitive strategies. Expanding the sample size and conducting longitudinal studies would improve generalizability and track skill development over time. Experimental research on instructional strategies and subject-specific analyses could further enhance insights into effective metacognitive regulation interventions.

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