EDUMATSAINS
JURNAL PENDIDIKAN MATEMATIKA DAN SAINS
E-ISSN:2527-7235
Volume 9 Issue. 2 January, 2025, pp 192-207
http://ejournal.uki.ac.id/index.php/edumatsains

The Analysis of Junior High School Students' Metacognitive Skills to Solve the Science Problems

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Article Info
Article history:
Received : December 2, 2024
Revised : January 14, 2025
Accepted : January 29, 2025
Available online : January 31, 2025

https://doi.org/10.33541/edumatsains.v9i2.6413

Abstract
In creating educational objectives aligned with the Learning Compass 2030, it is essential to establish a learning environment where students feel comfortable and to apply learning strategies suited to the characteristics of the learners. The objective of this research is to map students' metacognitive skills to understand their learning strategies in solving science-related problems. This study employs a mixed-methods approach, which involves collecting both quantitative and qualitative data, integrating the two forms of data, and using diverse research designs. The quantitative data were obtained from administering metacognitive skills tests and questionnaires, while qualitative data were gathered from student interviews. The research yielded several findings: (1) expert validity results for the metacognitive skills instrument indicated it is valid, (2) trial testing of the instrument showed it to be reliable and valid, (3) the profile of students' metacognitive skills across all indicators was found to be low in three different schools, and (4) there was a high response rate. The novelty of this research lies in its unique approach of mapping students' metacognitive skills in three different regions after the COVID-19 pandemic, providing valuable insights into the impact of the pandemic on students' learning strategies. By examining metacognitive skills in a post-pandemic context, this study contributes new perspectives on how students' learning strategies may have evolved or been affected by the pandemic, which has not been widely explored in previous studies.

Keywords: education, metacognitive skills, science education, science problems, thinking

1. Introduction

Currently, education in Indonesia faces significant challenges. One critical way to assess the progress of a country's education system is by examining the quality of formal education, as it reflects the behavior, attitudes, and character of its society through the application of knowledge in daily life. Based on the results of the Programme for International Student Assessment (PISA) 2023, the quality of Indonesia’s education has declined in the areas of science, mathematics, and reading (Organisation for Economic Co-operation and Development {OECD}, 2023). In science, Indonesia scored 398, in mathematics 379, and in reading 371. Alarmly, only 1% of Indonesian students scored at the higher levels (5 or 6), while the majority remained at lower levels (Lestari et al., 2024; OECD, 2023).

According to Lestari et al. (2021) and Lie et al. (2020), the decline in the quality of Indonesia's education is influenced by the distance learning implemented during the COVID-19 pandemic, which has led to increased learning loss. Learning loss can have a significant impact on students' cognitive processes. When students experience learning loss, they tend to have difficulty retaining previously learned information or gaining a deep understanding of new concepts. A shallow understanding of concepts, which does not align with expert understanding, can lead to misconceptions (Mubarokah, 2019).

The Learning Compass 2030 published by the OECD (2019) sets future educational and skills goals for young generations. The OECD outlines educational objectives aimed at helping children learn to adapt, grow, and be ready to face future challenges, as well as supporting them in developing not only knowledge and skills but also attitudes and values that will guide them in ethical and responsible actions. To achieve this goal, processes involving stakeholders, school principals, teachers, students, and parents are needed. One way to do this is by creating a learning environment that is as comfortable as possible for students to learn well and by implementing learning strategies suited to the students' characteristics (Putra et al., 2023).

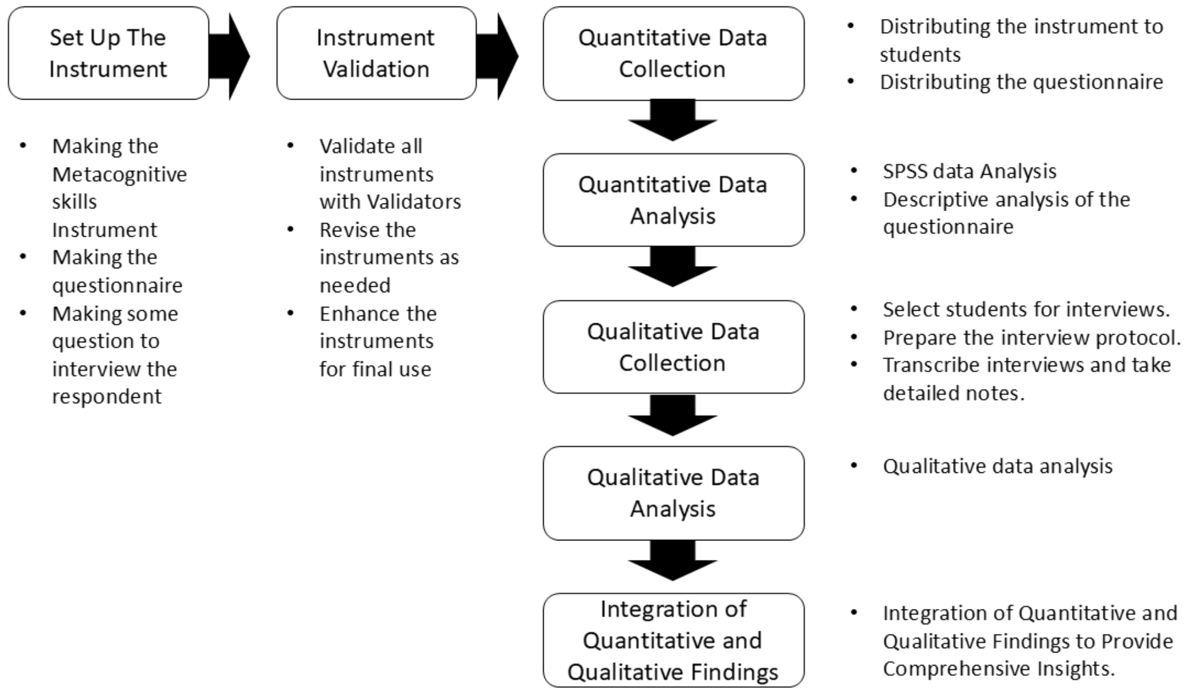
To enhance the quality of learning, it is essential to understand students’ thinking processes and learning strategies, particularly through metacognitive skills. Metacognitive skills are individuals’ awareness of their own thinking processes and their understanding of the patterns involved (Dewi et al., 2023; Jia et al., 2019). Metacognitive skills are crucial in education because their impact on the learning process is significant (Kikas & Jõgi, 2016). Haryani et al. (2014) state that metacognitive skills are necessary as students engage in cognitive processes to create a comfortable environment and design their own learning strategies. These skills are crucial for academic success as they help students identify effective strategies to solve problems and improve their learning (Fleming & Lau, 2014; Rangkuti et al., 2022). With metacognition, students can understand how they learn and develop learning strategies that suit their learning styles (Putra et al., 2023). For example, students with a strong understanding of metacognition might be better able to identify effective learning strategies, such as using schemas or concept maps to grasp complex scientific concepts. Thus, understanding metacognition not only helps students comprehend how they learn but also enables them to develop more effective and adaptive learning strategies.

However, in reality, students' metacognitive abilities are still low (Hidayah & Nabila, 2022; Safitri et al., 2020; Saputra & Andriyani, 2018; Suryaningtyas & Setyaningrum, 2020; Yasinta et al., 2023). The importance of developing these skills is further emphasized by the declining PISA scores, as metacognitive skills are key to improving students' problem-solving abilities and academic performance. By cultivating metacognitive awareness, students can adapt their learning strategies to be more effective, especially in subjects like science, which require abstract and systematic thinking OECD (2017). The decline in PISA scores highlights a critical gap in students' learning strategies, underscoring the need to map and develop their metacognitive skills. Research focusing on metacognitive skills in the post-pandemic context is essential to understanding how students' learning strategies may have changed and how these skills can be leveraged to improve academic outcomes. Mapping students' metacognitive skills can help identify effective learning patterns, enabling educators to better support students' cognitive development and enhance educational quality.

Based on Piaget's theory, during the formal operational stage at age 12 and above, when students begin middle school, they are capable of thinking abstractly, logically, and systematically (Cherry, 2023; Huitt & Hummel, 2003; Putra et al., 2023; Verma, 2024). At this age, students begin to reflect on their thinking processes and develop more effective learning strategies. Thiserves as the basis for selecting research subjects at the junior school level.

2. Methods

This research falls under the category of mixed methods research, which is a research approach that involves the collection of both quantitative and qualitative data, the integration of the two forms of data, and the use of different designs, potentially involving philosophical assumptions and theoretical frameworks (Creswell, 2014). The mixed methods approach was chosen to enhance the reliability of the quantitative findings by complementing them with insights from the qualitative data. This study specifically employed a Sequential Explanatory Design (can be seen in Figure 1), where quantitative data were collected and analyzed in the first phase, followed by the collection and analysis of qualitative data in the second phase. The qualitative phase was designed to provide deeper explanations and context to the initial quantitative results, ensuring a comprehensive understanding of the research problem.



(Henderson & Greene, 2014)

Figure 1. The flow of the Sequential Explanatory Design

The participants of this study comprised Grade 9 students from three schools: SMP Negeri 40 Surabaya, SMP Bustanul Makmur Banyuwangi, and SMPK St. Ignatius Loyola Labuan Bajo. In total, 85 students participated, distributed across these three institutions. The selected areas for this study were Surabaya, Banyuwangi, and NTT, chosen based on educational statistical data as well as geographic and socio-economic diversity. These regions were specifically selected to represent a broad spectrum of geographic contexts metropolitan cities, semi-urban areas, and island communities while also capturing socio-economic variations. These differences include disparities in educational environments, access to learning facilities, and the diverse backgrounds of students. The test item data will be analyzed using quantitative descriptive methods. The test results data will be analyzed using Equation 1 (Yasir et al., 2020) shown below:

$$y_2 = \frac{y_1 + 2x}{2} \qquad (1)$$

Explanation:

y_1 = cognitive test score

y_2 = combination of cognitive and psychomotor tests

x = psychomotor

After calculating using Equation 1, the obtained scores are then adjusted to Table 1, which shows the intervals for metacognitive skills, with the criteria for each indicator provided in Table 2.

Table 1. Metacognitive Skills Interval

Aspect	Indicator	Very Good	Good	Medium	Poor
Cognitive	Declarative	9-10	6-8	3-5	0-2
	Procedural	7-10	5-6	2-4	0-1
	Conditional	6-10	4-5	2-3	0-1
Psychomotor	Planning	8-10	6-7	2-5	0-1
	Monitoring	8-10	6-7	2-5	0-1
	Evaluation	6-10	4-5	2-3	0-1

Table 2. Criteria for Levels of Metacognitive Skills

Level of Metacognitive Skills	Description
Very Good	1. Declarative, procedural, and conditional skills are well developed. 2. Planning, monitoring, and evaluation skills have improved significantly.
Good	1. Declarative and procedural skills are well developed, but conditional skills are at a moderate level. 2. Planning and monitoring skills are well developed, but evaluation skills are at a moderate level.
Medium	1. Declarative skills are developing at a moderate level, but conditional and procedural skills are at a poor level. 2. Planning is developing at a moderate level, but monitoring and evaluation skills are at a poor level.
Poor	1. Declarative, procedural, and conditional skills are poorly developed.

	2. Planning, monitoring, and evaluation skills have not improved.

3. Result and Discussion

3.1. Expert Validation Results

This study aims to map students' metacognitive skills to understand their learning strategies in solving science problems. The metacognitive skills test instrument that has been designed needs to be validated by experts to obtain constructive feedback and suggestions for improving the test instrument. The aspects assessed by the expert validation include content, construction, and language. There are two validators who conducted the validation of the metacognitive skills test instrument. The assessment results can be seen in Table 3 below:

Table 3. Expert Validation Results

No.	**Aspect**	**Validator 1**	**Validator 2**	Average	Category
1.	Content	4.00	3.50	3.75	Valid
2.	Construction	3.75	3.75	3.75	Valid
3.	Language	4.00	4.00	4.00	Very Valid
Total		11.75	11.25	11.50	Valid
Average		3.92	3.75	3.83	Valid
Reliability		**95.83 %**			**Reliable**

Based on the expert validation results in Table 3, it can be observed that the overall average score for the metacognitive skills test in the content aspect is 3.75, categorized as valid. This suggests that, overall, the content of the material is considered appropriate and relevant by the evaluators. Both validators agreed on a score of 3.75 for the construction aspect, resulting in an average of 3.75. Categorized as "Valid," this indicates that the structure or organization of the material is generally satisfactory. Both validators found the construction to be consistent and appropriate for its intended purpose. Both validators gave a perfect score of 4.00 for the language aspect, which resulted in an average score of 4.00, categorized as "Very Valid." This high rating suggests that the language used in the material is clear, appropriate, and highly effective in conveying the intended message. The consistency in the scores across both validators indicates a strong agreement on the quality of the language. The reliability percentage is 95.83%, categorized as reliable, indicating that the assessments from the two validators are consistent. This indicates that the evaluation process is reliable and the results can be trusted. This shows that the metacognitive skills test instrument is suitable for use.

3.2. Reliability Test

Reliability refers to the accuracy and precision of a measurement tool used in an assessment. The results of the limited trial obtained statistical calculations using SPSS, as shown in the following table:

Table 5. Reliability Test Results

		N	%
Cases	Valid	25	100.0
	Excluded[a]	0	.0
	Total	25	100.0

a. Listwise deletion based on all variables in the procedure.

Cronbach's Alpha	N of Items
.751	10

Based on Table 5 the calculation results indicate a Cronbach's alpha value of 0.751, which is based on 10 items. A Cronbach's Alpha value of 0.751 suggests that the reliability of the instrument is acceptable, as values above 0.7 are generally considered to indicate good internal consistency. Therefore, the results indicate that the measurement tool demonstrates a reliable level of consistency across the 10 items assessed.

3.3. Difficulty Level

Difficulty level refers to the index of difficulty for items on a specific instrument. There are 10 essay questions in the metacognitive skills test instrument given to the students. The statistical calculation results using SPSS are shown in the following table:

Table 6. Difficulty Level Test Results

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
N	Valid	25	25	25	25	25	25	25	25	25	25
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		2.48	4.36	4.32	3.56	6.20	5.64	6.32	2.88	7.72	2.24
Difficulty Level		0.248	0.436	0.432	0.356	0.62	0.564	0.632	0.288	0.772	0.224
Category		Difficult	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Difficult	Easy	Difficult

The calculation results show the difficulty level for each test item. This table presents the difficulty level results for 10 items (B1 through B10) in a test. For each item, data was collected from 25 valid cases, with no missing values, as indicated by the "Missing" column showing 0 for all items. Items 1, 8, and 10 are considered difficult by students. Item 9 is considered easy, while items 2, 3, 4, 5, 6, and 7 are considered moderate. This suggests a well-balanced distribution of difficulty throughout the test items. Items considered too difficult or too easy need to be revised, as a good test item should not be too easy or too difficult.

3.4. Metacognitive Skills Profile

The profile data of metacognitive skills in solving science problems for Grade IX students from schools located in three regions (Surabaya, Banyuwangi, and NTT) can be seen in Table 7 and Figure 2 below:

Table 7. Metacognitive Skills Profile Results of Students

Location	**Indicator**					
	Declarative	**Procedural**	**Conditional**	**Planning**	**Monitoring**	**Evaluation**
School A in Surabaya	41.43	42.33	35.67	30.67	58.33	25.00
School B in Banyuwangi	55.19	63.71	52.57	46.29	62.57	42.29
School C in NTT	37.60	40.40	34.80	37.20	44.80	29.60

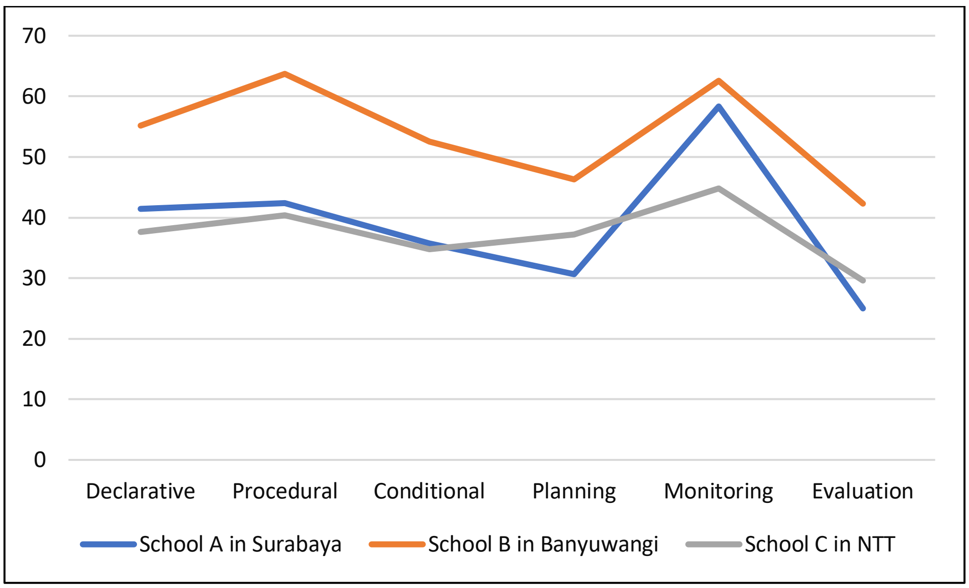


Figure 2. Metacognitive Skills Profile of Students

Based on Table 7 and Figure 2, School B in Banyuwangi has a higher metacognitive skills profile compared to School A in Surabaya and School C in NTT. The lowest metacognitive skills profile is found in School C in NTT. This is because the area where School B in Banyuwangi is located has a higher socioeconomic status, while School A in Surabaya has a medium socioeconomic status, and School C in NTT is in an area with a low socioeconomic status. Schools in low socioeconomic areas often face challenges in providing adequate educational resources. This can affect the quality of education received by the students and, in turn, influence their metacognitive skills (Syahdan, 2020; Widiansyah, 2018). Additionally, inappropriate learning strategies can impact students' metacognitive skills. Teaching methods that do not allow students to actively participate can reduce their ability to plan, monitor, and evaluate their own learning process (Prasetyoningrum & Mahmudi, 2017). This may affect students' metacognitive skills because they are not trained to reflect on their learning process.

When looking at metacognitive skills by indicator, the declarative indicator in School B in Banyuwangi has a percentage of 55.19%, higher than School A in Surabaya at 41.43%, and School C in NTT at 37.60%. This means that 55.19% of students at School B in Banyuwangi can understand issues related to the excretory system in the kidneys and nerve cells from the given phenomena (questions no. 1 & no. 2), can connect prior knowledge to solve problems related to the relationship between running and human blood pressure (question no. 3), can relate the impact of a volcanic eruption on the Earth's temperature (question no. 4), and can connect the effects of smoke from burning trash to respiratory system disorders (question no. 5). This indicates that students at School B in Banyuwangi have good skills in storing information and understanding scientific problems. Declarative knowledge helps students identify important ideas and organize information to solve scientific problems (Damayanti et al., 2021; Wardana et al., 2020).

The procedural indicator in School B in Banyuwangi has a percentage of 63.71%, higher than School A in Surabaya at 42.33% and School C in NTT at 40.40%. This indicates that students can mention the steps to address symptoms of digestive disorders (question no. 6). The students' procedural metacognitive skills help them set goals, provide supporting factors, and manage time to solve scientific problems (Wardawaty et al., 2018).

The conditional indicator in School B in Banyuwangi has a percentage of 52.57%, higher than School A in Surabaya at 35.67% and School C in NTT at 34.80%. Metacognitive skills under the conditional indicator help students to understand the appropriate context for using declarative and procedural knowledge in solving scientific problems (Armayanti & Hidayah, 2022). The students know when and why to choose a particular type of lens to correct visual impairment (question no. 7).

The planning indicator in School B in Banyuwangi has a percentage of 46.29%, higher than School A in Surabaya at 30.67% and School C in NTT at 37.20%. However, all three schools have a planning indicator percentage below 50%, meaning students' planning skills are not optimal. This is evident from their inability to redesign a swing appropriately based on the given problem

(question no. 8). Students with good planning indicators can set specific and realistic goals, as suggested by Iskandar (2014) and can redesign the swing based on the problem.
The monitoring indicator in School B in Banyuwangi has a percentage of 62.57%, higher than School A in Surabaya at 58.33% and School C in NTT at 44.80%. According to this data, two regions have a percentage above 50%. Students are able to check the correct answer based on the criteria for stopping continuous blood flow (question no. 9). Students with metacognitive skills in the monitoring indicator can control their cognitive activities, especially during problem-solving (Afifi et al., 2016).
The evaluation indicator in all three regions (Surabaya, Banyuwangi, and NTT) has a percentage below 50%, indicating that this skill is not optimal in these schools. Ideally, students with metacognitive skills in the evaluation indicator can assess their level of understanding and determine the most appropriate strategy (Iskandar, 2014). These skills would allow students to choose the best strategy for solving scientific problems. However, in reality, this skill is not yet fully developed, as students in all three schools struggle to decide the best way to separate seawater into freshwater (question no. 10).

3.5. Questionnaire

The questionnaire was distributed to all students who filled out the metacognitive skills test instrument. The indicators assessed in the questionnaire include declarative, procedural, conditional, planning, monitoring, and evaluation. The results of the questionnaire data from the three schools can be seen in Table 8, and the graphical data from the questionnaire can be viewed in Figure 3.

Table 8. Results of Student Questionnaire

Location	**Indicator**					
	Declarative	**Procedural**	**Conditional**	**Planning**	**Monitoring**	**Evaluation**
School A in Surabaya	70.98	72.32	73.21	87.05	89.28	81.25
School B in Banyuwangi	74.61	67.19	77.34	82.42	81.25	77.34
School C in NTT	76.50	71.50	79.00	82.00	88.00	82.50

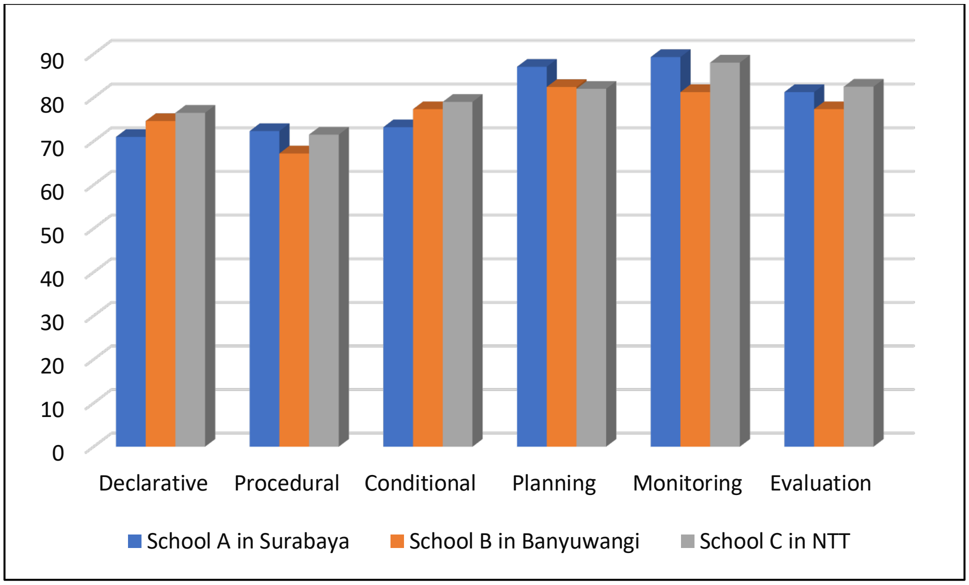


Figure 3. Graph of Metacognitive Skills Questionnaire Data

Based on the results of the questionnaire shown in Table 6, the responses of students from three different schools with the same educational level were varied. On the declarative indicator, the percentage of students who were able to manage important information and remember it well to solve scientific problems was 70.98% at School A in Surabaya, 74.61% at School B in Banyuwangi, and 76.50% at School C in NTT. These results do not align with the low metacognitive skills test profile observed in each school. On the procedural indicator, 72.32% of students from School A in Surabaya, 67.19% from School B in Banyuwangi, and 71.50% from School C in NTT were able to identify and find information on their own to solve scientific problems. However, these results are not consistent with the metacognitive skills shown in the three schools.

For the conditional indicator, 73.21% of students at School A in Surabaya, 77.34% at School B in Banyuwangi, and 79.00% at School C in NTT could think of several approaches and determine the best way to solve scientific problems. These results do not match the low metacognitive skills test profile at the three schools. On the planning indicator, the percentage of students who could redesign solutions based on the scientific problems given was lower than their metacognitive skills profile, with 87.05% at School A in Surabaya, 82.42% at School B in Banyuwangi, and 82.00% at School C in NTT.

On the monitoring indicator, 89.28% of students from School A in Surabaya, 81.25% from School B in Banyuwangi, and 88% from School C in NTT showed that they were able to review whether what they had done was correct. The results of the monitoring indicator in the questionnaire and the metacognitive skills profile showed different outcomes, but in the metacognitive skills test, this indicator had the highest score compared to the others. On the evaluation indicator, students were able to decide on the best way to solve scientific problems, with 81.25% at School A in Surabaya, 77.34% at School B in Banyuwangi, and 82.5% at School C in NTT. These results do not match the low metacognitive skills profile at the three different schools.

Overall, it can be concluded that the students' metacognitive skills test scores and the questionnaire results were very different. The metacognitive skills test scores of students in the three different schools were still low and require improvement to train students to better use their abilities in solving scientific problems. These results align with Afni et al. (2020), who state that students have not yet fully utilized their abilities to solve scientific problems.

The interview was conducted with students who had high, medium, and low scores. This stage aimed to gain a deeper understanding of how students think and how they use metacognitive skills in solving science problems. Students were presented with two illustrations of science problems: one concerning stopping continuous bleeding and the other regarding a boat that does not easily sink when used to transport.

3.6. Interview

Based on Table 7, Table 8, and Table 9, it appears that students were able to understand information, manage it well, list steps for problem-solving, select and explain reasons for choosing a solution, plan the solution, review the solution, and decide on the best solution for the given problem illustrations. However, at School C in NTT, a non-scientific solution was found, where students suggested using coffee to stop bleeding. This indicates the need to train students at School C in NTT on the conditional indicator. In terms of the declarative, procedural, conditional, planning, monitoring, and evaluation indicators, there was progress in all three regions. Overall, the results of the questionnaire and the interview are aligned, but they differ from the metacognitive skills profile results. This is in line with the opinion of Afni et al. (2020), who suggest that students' metacognitive skills are not yet fully utilized when solving scientific problems.

4. Conclusion

This study provides valuable insights into the metacognitive skills of Grade IX students from schools in Surabaya, Banyuwangi, and NTT, as well as the effectiveness of the developed metacognitive skills test instrument. The expert validation results confirmed that the test instrument is valid, with a high reliability score of 95.83%, indicating consistent and trustworthy evaluations. The reliability test further supported the instrument's internal consistency, with a Cronbach's Alpha of 0.751. The difficulty level of the test items was well-balanced, though some items may need revision to avoid extremes in difficulty.

The metacognitive skills profiles revealed that students from School B in Banyuwangi performed better than those from School A in Surabaya and School C in NTT, with socioeconomic factors influencing these differences. Students from lower socioeconomic regions, such as those in School C, demonstrated lower metacognitive skills, highlighting the need for targeted interventions. While questionnaire responses indicated higher self-reported metacognitive skills, these did not always align with students' actual problem-solving abilities, suggesting a gap between self-awareness and performance. Interviews confirmed that, while students could demonstrate metacognitive skills, misconceptions were noted, particularly in School C, emphasizing the need for additional training in conditional metacognitive skills.

Overall, the study underscores the importance of improving metacognitive skills, particularly in regions with lower socioeconomic status, through targeted educational strategies and enhanced teaching methods. Further training and refined assessments will help students better apply their metacognitive skills in solving scientific problems.

5. Aknowledgments

The author's gratitude goes to Ministry of Research, Technology and Higher Education Indonesia for funding this research. Likewise, the author's appreciation goes to Universitas Nahdlatul Ulama Pasuruan, Widya Mandala Surabaya Catholic University, SMP Negeri 40 Surabaya, SMP Bustanul Makmur Banyuwangi, and SMPK St. Ignatius Loyola Labuan Bajo for providing the opportunity to collect data in this research.

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