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Analysis of Student's Metacognitive Errors in Working on PISA-Like Math Problem on Number Content

[1]Hanayuki Alya, [2]Jenny Nurika Aryani, [3]Aliyyah Salsabila, [4]Ratu Ilma Indra Putri, [5*]Elsa Susanti, & [6]Ruth Helen Simarmata
[1]Department of Mathematics Education, Universitas Sriwijaya, Indonesia.
[1]elsasusanti@fkip.unsri.ac.id*

Abstract

This study aims to analyze the forms of metacognitive errors made by junior high school students in solving questions developed by the Programme for International Student Assessment (PISA) on number content. Metacognitive skills are part of a higher-order thinking process that includes awareness and control of one's own thinking process, including strategy planning, monitoring implementation, and evaluating results. In the context of PISA-like math problem that require contextual and complex problem solving, these skills are crucial. This study employed a qualitative approach using a case study design. The research subjects consisted of three VIII grade students who were identified according to the categories of high, medium, and low mathematical ability. The main instruments were PISA-like math problem and interview guidelines based on metacognitive indicators. Data were obtained using written assessments and comprehensive interviews, then examined through qualitative descriptive analysis. The results showed that all students, regardless of mathematics ability level, made metacognitive errors. The most dominant errors occurred at the planning and evaluation stages. Students with low ability had difficulty understanding the problem, identifying relevant information, and designing a solution strategy. While students with medium and high abilities tend not to evaluate steps and results optimally. The results underscore the significance of enharing metacognitive abilities in mathematics education to foster reflective thinking and tackle complex problems.

Keywords: Metacognitive errors, PISA, Number, Junior high school, Problem solving.

Introduction

From an early age, education is carried out in a directed manner to develop the potential of intelligence for the progress of the country (Hakim & Hendriana, 2022). Education in the 21st century faces various challenges that are increasingly diverse and complex, many of which are driven by rapid technological developments that change how people live, work, and learn (Chusna et al., 2024). In this context, education can no longer focus only on reading and memorizing, but must also develop 21st-century skills such as critical thinking, creativity, collaboration, and problem solving in real-life situations (Maulidia et al., 2023). Students interact with digital devices, social media, and technology-based learning platforms that continuously present quantitative information in the form of numbers, tables, graphs, and data visualizations. This condition makes numeracy literacy a core 21st-century competence, because it refers to students' ability to apply mathematical concepts, understand quantitative information, and interpret it to make appropriate decisions in everyday contexts (Ermiana et al., 2021). Numeracy literacy is therefore positioned as part of the fundamental literacy that every student needs to have (Izzatin et al., 2022). At the same time, mathematical literacy has a broader scope than numeracy literacy, because it not only involves working with numbers, but also includes the ability to formulate, employ, and interpret mathematics in various situations, both with and without explicit numerical symbols (Matondang et al., 2023). In this study, numeracy literacy is viewed as a concrete manifestation of mathematical literacy in the context of number content. Therefore, strengthening students' numeracy literacy skills needs to be prioritized in mathematics learning as an effort to prepare them to face complex problems in the 21st century (Habibi & Prahmana, 2022).

One of the programs to assess students' mathematical literacy developed by the OECD is the Programme for International Student Assessment or PISA (Aini et al., 2022). A particular country involved in this PISA is Indonesia (Bana et al., 2021). PISA is based on a contextual mathematics approach to assess the extent to which students are able to apply their mathematical knowledge in real life (Wulandari & Warmi, 2022). Based on the latest PISA report, although Indonesia experienced an increase in rankings in math and numeracy literacy, the average score actually decreased to 366, down 13 points from 2018. This score lags 106 points below the world average, with around 82% of students falling below level two in the low ability category (OECD, 2023). This report shows that Indonesian students are still below international standards (Hamda et al., 2024). This condition is not only caused by a lack of understanding of mathematical concepts. One of the other factors that contributes to students' low numeracy literacy skills is their metacognitive aspect (Wahyuningsih & Waluya, 2017).

Metacognition refers to students' awareness and regulation of their own thinking processes, including how they plan, monitor, and evaluate what they (Sari et al., 2024). When metacognitive awareness is well developed, students are better able to select appropriate strategies, control errors, and reflect on their understanding, which in turn improves their problem-solving performance and mathematical literacy skills (Handayani et al., 2022). Conversely, students who rarely engage in metacognitive activities, such as checking or revising their solution steps, tend to experience persistent difficulties in answering mathematical problems (Hidayah & Nabila, 2022).

Students' difficulties in answering mathematical problems, as caused by the lack of training in metacognitive skills, are reflected in the various mistakes they make in solving PISA problems. This contributed to the low achievement of students in the test, as indicated by the many errors that appeared during the problem-solving process (Pranitasari & Ratu, 2020). Number content is one of the crucial aspects in learning mathematics because it is directly related to students' basic understanding of numerical relationships and operations in everyday situations (Habibi & Prahmana, 2022). In PISA-like assessments, this content often appears in tasks that require students to compare quantities, interpret percentages and ratios in realistic contexts such as prices, population data, or consumption, and decide which option is more economical based on unit prices (Saputri et al., 2020). Other number-content problems ask students to read and interpret numerical information presented in tables or simple graphs and then draw conclusions or make decisions based on that information (Noviana & Murtiyasa, 2020). These types of tasks place high cognitive demands on students because they must identify relevant information, translate a verbal or contextual situation into an appropriate mathematical model, perform multi-step calculations accurately, and assess whether the final result is reasonable in the given context.

From a metacognitive perspective, number-content tasks require students to plan their solution strategies by deciding what is known, what is asked, and which operations or representations are most appropriate before starting to calculate. During the solving process, students need to monitor each step, for example by checking whether the procedure used is consistent with the information given in the problem. At the end, they are expected to evaluate whether the obtained answer makes sense in the real situation described. When these metacognitive processes of planning, monitoring, and evaluation are weak, students tend to misread numerical data, choose inappropriate operations, or accept unreasonable results without rechecking. Therefore, it is necessary to analyze how students think metacognitively and the sources of errors in their answers to PISA-like math problems on this content.

Previous research has analyzed students' metacognitive abilities in terms of brain dominance (Lusiana et al., 2020). Another study also analyzed the students' metacognition profiles in terms of gender (Aulia & Murtiyasa, 2023). In addition, Hidayah and Nabila (2022) analyzed the ability of metacognition on the Pythagorean theorem material. However, research that specifically analyzes errors in the answers to PISA-like math problem on number content for grade VIII junior high school students from the perspective of metacognitive indicators is still very limited.

Building on the previous studies, there is still a lack of research that specifically examines students’ metacognitive errors when solving PISA-like math problems on number content at the junior high school level. Therefore, this study aims to identify and analyze the types of metacognitive errors that students make in the dimensions of metacognitive knowledge, metacognitive regulation, and metacognitive experience when solving PISA-like math problems on number content, using a qualitative descriptive analysis of their written work and interview responses. The findings of this study are expected to contribute to the development of learning strategies that explicitly foster metacognitive awareness and numeracy literacy, as well as to improve the readiness of Indonesian students in facing international assessments such as PISA in the future.

Methods

This study employed a qualitative descriptive design to characterize students’ errors in solving PISA-like math problems based on metacognitive indicators. This design enables an in-depth exploration of students’ thinking processes while they solve problems, particularly how they plan, monitor, and evaluate their strategies. The analysis focuses not only on whether the final answers are correct, but also on the sequence of solution steps and the metacognitive breakdowns that occur during the problem-solving process.

In this study, three eighth-grade students aged 15 years were selected in accordance with the PISA target age group. They were drawn from a state junior high school located in Sako Kenten District, Palembang. The school is a public institution that implements the national curriculum and has several parallel classes at each grade level, serving students from a range of socio-economic backgrounds that are typical of urban public schools in the area. This context makes the school setting representative of a regular lower-secondary mathematics learning environment in Indonesia, so that the cases can provide illustrative insight even though the findings are not intended for statistical generalisation. The three focal students were chosen to represent high, medium, and low levels of mathematical ability based on their mathematics achievement records over the previous months and teacher recommendations. The selection of subjects was carried out using purposive sampling, namely recruiting participants who met predefined criteria relevant to the focus of the study (Pusvitasari & Mifti Jayanti, 2021).

The main research instrument was a written test consisting of PISA-like math problems on number content from levels 1 to 6. However, for the purposes of metacognitive error analysis, this study focused only on students' responses to the level 3 and level 5 items. Questions at levels 1 and 2 were generally answered correctly by all students and were presented in non-descriptive formats (short answers), so they did not provide sufficient written work to trace students' thinking processes and error patterns. Meanwhile, the level 4 and level 6 items, although more complex, tended to elicit very similar solution paths across students, which limited the variation needed for qualitative comparison of metacognitive errors. In contrast, the level 3 and level 5 items produced diverse and unique solution strategies for each student, making them more informative for analysing how metacognitive breakdowns occur. The PISA-like problems used in this study were developed by the researchers through a series of self-assessment, expert review, one-to-one, and small-group trials. The validity coefficients obtained were 0.706 for the level 3 item and 0.652 for the level 5 item, with reliability coefficients of 0.416 and 0.463 respectively, indicating that the items were suitable for use in this exploratory qualitative study.

The purpose of this study was to analyze students' errors in solving PISA-like math problem based on three metacognitive dimensions, namely metacognitive knowledge, metacognitive regulation, and metacognitive experience. The research instrument was a written test based on the PISA context designed to reveal students' thinking strategies and error patterns.

Analysis was conducted on students' answers by grouping errors based on indicators: (1) Metacognitive knowledge includes errors in choosing strategies, inappropriate understanding of concepts, and inappropriate approaches to the type of questions; (2) Metacognitive regulation includes the inability to evaluate solutions, monitor work steps, and failure to correct repeated errors; and (3) Metacognitive experience includes students' responses to uncertainty, the tendency to ignore instructions, and the behavior of giving up or answering without trying (TV & Musthafa, 2024).

This study involved three students from class VIII at one of the junior high schools in Palembang city. The subjects were selected based on the grouping of students into categories with high, low, and medium mathematical abilities. The selection of these categories was based on the researchers' discussion following the progress of students' learning outcomes reports over the past few months. The selected subjects were categorized by the researcher, as can be seen in Table 1.

Table 1
Research Subjects Selected Based on Ability Level

No	Name	Learning Style
1	S-1	High
2	S-2	Middle
3	S-3	Low

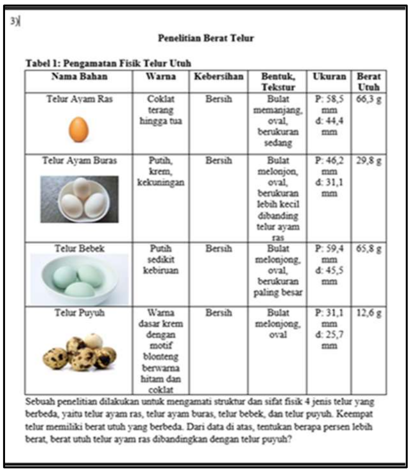
Results and Discussion

The following are the results and discussion of the research data of subjects S-1, S-2, and S-3 regarding two PISA-like math problem on number content.

PISA-Like Math Problem Level 3

The level 3 PISA-like math problem was developed in accordance with the PISA level 3 framework, in which students are expected to describe the problem clearly and carry out calculation procedures that require simple decision-making. At this level, students should be able to interpret and use representations based on various sources of information and reason directly from the problem situation.

Figure 1 (a) presents the Indonesian version of the level 3 item. The problem displays a table titled *Penelitian Berat Telur* that summarises the physical observations of four types of eggs (telur ayam ras, telur ayam buras, telur bebek, and telur puyuh), including their colour, cleanliness, shape/texture, size, and whole weight. At the bottom of the table, students are asked, based on the weight data, to determine by how many percent more the whole weight of a chicken egg is compared with a quail egg. Figure 1(b) illustrates the same problem in English (Egg Weight Research), featuring an identical table structure and question translated into English. These figures illustrate that students must read and select relevant numerical information from a data table, decide which quantities to compare, and then perform percentage calculations in a realistic context.


3)

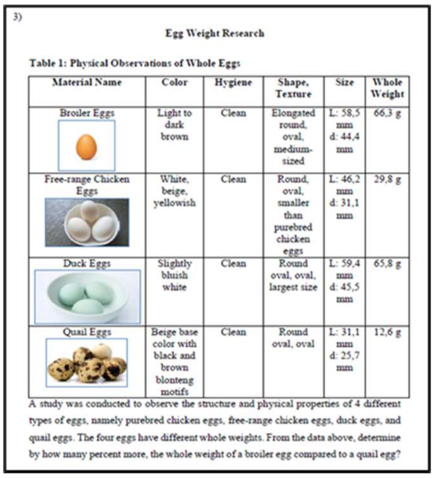
Penelitian Berat Telur

Tabel 1: Pengamatan Fisik Telur Utuh

Nama Bahan	Warna	Kebersihan	Bentuk, Tekstur	Ukuran	Berat Utuh
Telur Ayam Ras	Coklat terang hingga tua	Bersih	Bulat memanjang, oval, berukuran sedang	P: 58,5 mm d: 44,4 mm	66,3 g
Telur Ayam Buras	Putih, krem, kekuningan	Bersih	Bulat melonjon, oval, berukuran lebih kecil dibanding telur ayam ras	P: 46,2 mm d: 31,1 mm	29,8 g
Telur Bebek	Putih sedikit kebiruan	Bersih	Bulat melonjong, oval, berukuran paling besar	P: 59,4 mm d: 45,5 mm	65,8 g
Telur Puyuh	Warna dasar krem dengan motif blonteng berwarna hitam dan coklat	Bersih	Bulat melonjong, oval	P: 31,1 mm d: 25,7 mm	12,6 g

Sebuah penelitian dilakukan untuk mengamati struktur dan sifat fisik 4 jenis telur yang berbeda, yaitu telur ayam ras, telur ayam buras, telur bebek, dan telur puyuh. Keempat telur memiliki berat utuh yang berbeda. Dari data di atas, tentukan berapa persen lebih berat, berat utuh telur ayam ras dibandingkan dengan telur puyuh?

(a)


3)

Egg Weight Research

Table 1: Physical Observations of Whole Eggs

Material Name	Color	Hygiene	Shape, Texture	Size	Whole Weight
Broiler Eggs	Light to dark brown	Clean	Elongated round, oval, medium-sized	L: 58,5 mm d: 44,4 mm	66,3 g
Free-range Chicken Eggs	White, beige, yellowish	Clean	Round, oval, smaller than purebred chicken eggs	L: 46,2 mm d: 31,1 mm	29,8 g
Duck Eggs	Slightly bluish white	Clean	Round oval, oval, largest size	L: 59,4 mm d: 45,5 mm	65,8 g
Quail Eggs	Beige base color with black and brown blonteng motifs	Clean	Round oval, oval	L: 31,1 mm d: 25,7 mm	12,6 g

A study was conducted to observe the structure and physical properties of 4 different types of eggs, namely purebred chicken eggs, free-range chicken eggs, duck eggs, and quail eggs. The four eggs have different whole weights. From the data above, determine by how many percent more, the whole weight of a broiler egg compared to a quail egg?

(b)

Figure 1. PISA-Like Math Problems Level 3; (a) Indonesian Version (b) English Version

Error Analysis of Subjects with High Mathematical Ability (S-1)

Figure 2 displays S-1's work on the level 3 problem. The left panel shows the original handwritten solution, while the right panel shows the English transcription. S-1 first writes the known data (whole chicken egg = 66.3; quail egg = 12.6) and correctly sets up the expression $(66.3 - 12.6)/12.6 \times 100\%$. In the next line, however, the subtraction result is written as 53.5 instead of the correct value, and this quantity is then divided by 12.6 and simplified to 4.2 before being taken as the final answer. Thus, Figure 2 illustrates that S-1 was able to identify the relevant information and choose an appropriate strategy, but made an unchecked numerical error in the intermediate subtraction step and accepted the resulting value without reconsidering whether it was reasonable.

Subject S-1 obtained a total score of 5, which indicates that overall, the subject was able to answer the question correctly and in accordance with the researcher's expectations. The student showed the ability to identify important information needed to compare the mass between whole chicken eggs and quail eggs, and the chosen solution strategy was appropriate, so no errors were found in the metacognitive knowledge dimension. However, the miswritten value 53.5 and the absence of any visible re-checking of the calculation show a weakness in metacognitive regulation: S-1 did not thoroughly monitor or evaluate the working steps and numerical results. In terms of metacognitive experience, the student also did not show any indication of noticing this inconsistency, suggesting limited reflective awareness of the thinking process and the accuracy of the final written answer.

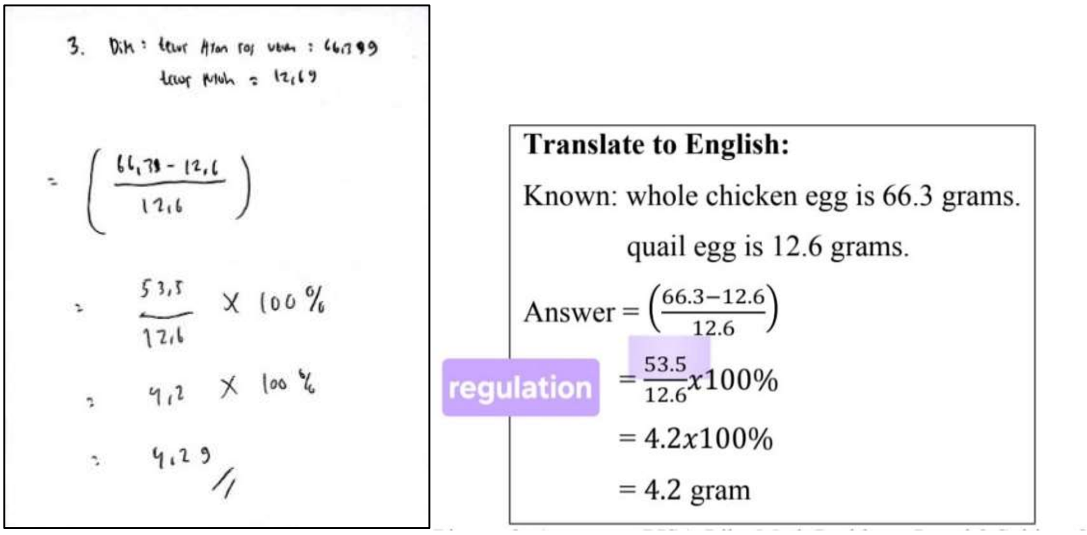


Figure 2. Answer to PISA-Like Math Problems Level 3 Subject S-1

Error Analysis of Subjects with Moderate Mathematical Ability (S-2)

Figure 3 shows S-2's written solution to the level 3 problem. The student first writes the known data, namely the whole weight of the purebred chicken egg (66.3) and the whole weight of the quail egg (12.6), then sets up the percentage formula $(66.3 - 12.6)/12.6 \times 100\%$. In the next lines, S-2 rewrites the result of the subtraction as 53.7, then expresses it as a fraction $53.7/12.6 = 537/126$. The calculator result is written as 4.261, which is then multiplied by 100% and finally rounded to 426.1%. Thus, Figure 3 illustrates that the solution strategy and initial representation are appropriate, but the numerical manipulation and interpretation of the decimal result lead to an unreasonable final percentage.

Subject S-2 has therefore been able to choose a solution strategy that aligns with the researcher's expectations, indicating a good initial understanding of the problem. However, the final answer written by S-2 does not match the answer key. During the solving process, the student raised a question about how to divide numbers in decimal form, especially when dealing with numbers containing commas. To simplify the calculation, the researcher suggested converting the percentage into a common fraction, namely, $100\% = 100/100$. Even after receiving this guidance, S-2 appeared momentarily confused about the conversion step but continued working without seeking further clarification or verifying whether the intermediate results were reasonable (for example, whether a value greater than 400% was sensible in this context). This behaviour indicates an error in the metacognitive experience dimension, namely limited awareness of one's own uncertainty and failure to act when confusion arises. The student did not show reflection on the difficulty experienced and did not take additional steps, such as re-checking calculations or asking follow-up questions, to ensure that the chosen process was correct. As a result, the initial correct strategy did not lead to a correct final answer because the thinking process was not monitored and evaluated adequately.

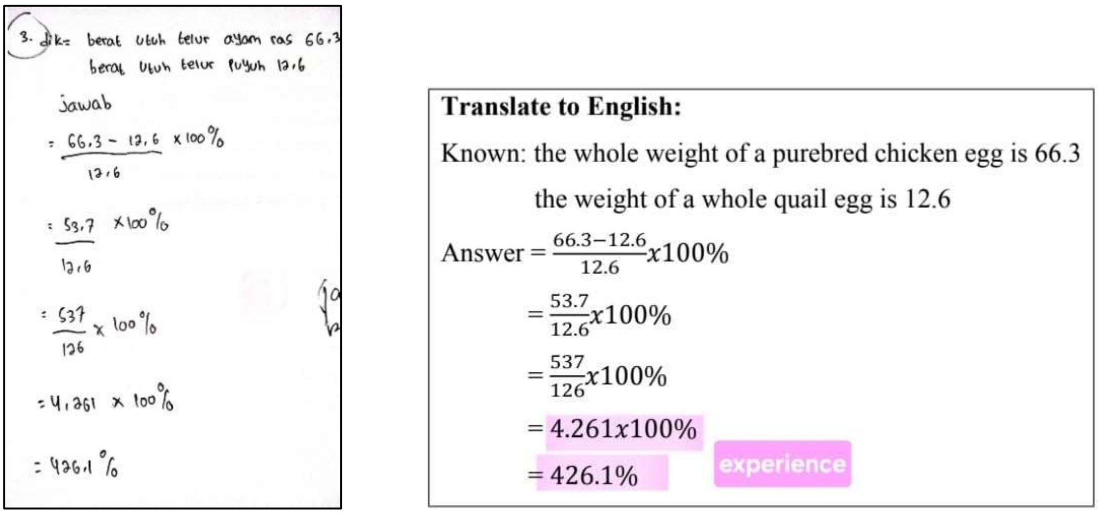


Figure 3. Answer to PISA-Like Math Problems Level 3 Subject S-2

Error Analysis of Subjects with Low Mathematical Ability (S-3)

Figure 4 shows S-3's solution to the level 3 problem. On the first line, the student writes the known data as a subtraction, $66.3 - 12.6 = 53.7$, which is numerically correct. In the next step, this result is placed over 12.6 in the fraction $\frac{53.7}{12.6} \times 100\%$. However, instead of computing the quotient, S-3 rewrites it as $45.6 \times 100\%$and then records the final answer as 4560%. The English transcription on the right panel presents the same sequence of steps and highlights the fraction line and the extreme percentage value as indicators of conceptual and regulatory errors. This work shows that S-3 experiences serious difficulties in both metacognitive knowledge and metacognitive regulation. From the knowledge dimension, although the student is able to identify the numbers that need to be compared and set up a percentage expression, the way $\frac{53.7}{12.6}$is processed into 45.6 and then into 4560% indicates that the basic concept of ratio and percentage is not yet understood. The student treats the numbers procedurally without a clear grasp of what the operations represent, so the final result becomes far from reasonable for a comparison of egg weights. From the regulatory dimension, there are no correction marks, alternative attempts, or indications that the student questions whether a value of 4560% is sensible in this context. This suggests that S-3 does not monitor or evaluate the solution steps, nor does he reflect on the plausibility of the result. The combination of incorrect conceptual application and lack of self-checking illustrates simultaneous weaknesses in declarative/procedural knowledge and in the regulation of the problem-solving process.

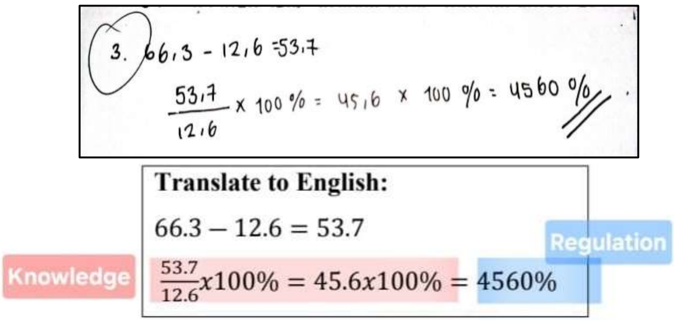
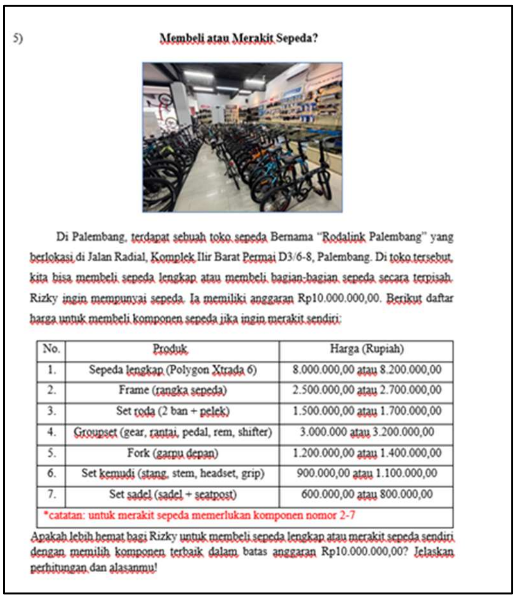


Figure 4. Answer to PISA-Like Math Problems Level 3 Subject S-3

PISA-Like Math Problem Level 5

PISA level 5 questions, according to the OECD framework, are questions of high complexity that require students to think reflectively, use abstract reasoning, and apply mathematical concepts in non-routine situations. At this level, students are expected to develop and work with complex mathematical models, design efficient problem-solving strategies, and interpret and evaluate results logically in real-life contexts.

Figure 5 presents the Indonesian version of the Level 5 item, entitled "Membeli atau Merakit Sepeda?" The problem describes a bicycle shop in Palembang and provides a price list for purchasing either a complete bicycle or separate components, including the frame, wheel set, groupset, fork, handlebar set, and saddle. A note under the table explains that to assemble a bicycle, component numbers 2–7 are required. The question then asks whether it is more cost-effective for Rizky, who has a budget of Rp10,000,000, to buy a complete bicycle or to assemble one from separate parts, and requires students to justify their choice with calculations and reasons. Figure 7 illustrates the same problem translated into English under the title "Buy or Build a Bike?", with the same table structure, prices, and question wording adjusted for English. These figures illustrate that students must interpret contextual information, select relevant prices, form a numerical model for minimum and maximum assembly costs, and compare these with the price of a complete bicycle within a budget constraint.



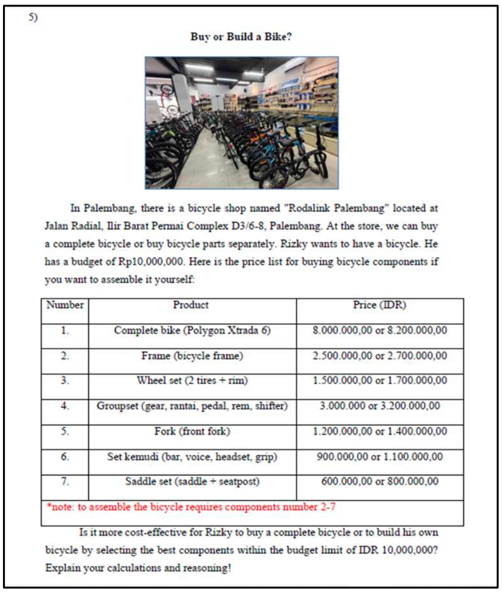
5) **Membeli atau Merakit Sepeda?**

Di Palembang, terdapat sebuah toko sepeda Bernama "Rodalink Palembang" yang berlokasi di Jalan Radial, Komplek Ilir Barat Permai D3/6-8, Palembang. Di toko tersebut, kita bisa membeli sepeda lengkap atau membeli bagian-bagian sepeda secara terpisah. Rizky ingin mempunyai sepeda. Ia memiliki anggaran Rp10.000.000,00. Berikut daftar harga untuk membeli komponen sepeda jika ingin merakit sendiri:

No.	Produk	Harga (Rupiah)
1.	Sepeda lengkap (Polygon Xtrada 6)	8.000.000,00 atau 8.200.000,00
2.	Frame (rangka sepeda)	2.500.000,00 atau 2.700.000,00
3.	Set roda (2 ban + pelek)	1.500.000,00 atau 1.700.000,00
4.	Groupset (gear, rantai, pedal, rem, shifter)	3.000.000 atau 3.200.000,00
5.	Fork (garpu depan)	1.200.000,00 atau 1.400.000,00
6.	Set kemudi (stang, stem, headset, grip)	900.000,00 atau 1.100.000,00
7.	Set sadel (sadel + seatpost)	600.000,00 atau 800.000,00
*catatan: untuk merakit sepeda memerlukan komponen nomor 2-7		

Apakah lebih hemat bagi Rizky untuk membeli sepeda lengkap atau merakit sepeda sendiri dengan memilih komponen terbaik dalam batas anggaran Rp10.000.000,00? Jelaskan perhitungan dan alasanmu!

(a)



5) **Buy or Build a Bike?**

In Palembang, there is a bicycle shop named "Rodalink Palembang" located at Jalan Radial, Ilir Barat Permai Complex D3/6-8, Palembang. At the store, we can buy a complete bicycle or buy bicycle parts separately. Rizky wants to have a bicycle. He has a budget of Rp10,000,000. Here is the price list for buying bicycle components if you want to assemble it yourself:

Number	Product	Price (IDR)
1.	Complete bike (Polygon Xtrada 6)	8.000.000,00 or 8.200.000,00
2.	Frame (bicycle frame)	2.500.000,00 or 2.700.000,00
3.	Wheel set (2 tires + rim)	1.500.000,00 or 1.700.000,00
4.	Groupset (gear, rantai, pedal, rem, shifter)	3.000.000 or 3.200.000,00
5.	Fork (front fork)	1.200.000,00 or 1.400.000,00
6.	Set kemudi (bar, voice, headset, grip)	900.000,00 or 1.100.000,00
7.	Saddle set (saddle + seatpost)	600.000,00 or 800.000,00
*note: to assemble the bicycle requires components number 2-7		

Is it more cost-effective for Rizky to buy a complete bicycle or to build his own bicycle by selecting the best components within the budget limit of IDR 10,000,000? Explain your calculations and reasoning!

(b)

Figure 5. PISA-Like Math Problems Level 5 (a) Indonesian Version (b) English Version

Error Analysis of Subjects with High Mathematical Ability (S-1)

Figure 6 shows S-1's written solution to the level 5 problem. In the upper part of the work, the student calculates the lowest prices of the required components (frame, wheel set, groupset, fork, handlebar set, and saddle) and obtains a minimum assembly cost of Rp 8,700,000. In the following lines, S-1 then considers a higher combination of prices and records a maximum assembly cost of Rp 9,300,000. Finally, S-1 writes a concluding sentence stating that it is more economical to buy a complete bicycle because there will still be money left over from the Rp10,000,000 budget. However, in this written explanation, the actual price range of the complete bicycle (Rp8,000,000–Rp8,200,000) is not explicitly stated.

Based on student S-1's answer, it can be analysed that he has chosen a solution strategy that is in accordance with the context of the problem, namely comparing the total price of the assembled bicycle and the complete bicycle. From the metacognitive knowledge dimension, the student shows an understanding of the right concepts and strategies, but does not explicitly include the price of the complete bicycle as the basis for comparison. This shows a deficiency in the declarative knowledge aspect, namely not mentioning important facts that should be included in the answer. In terms of metacognitive regulation, the student has not fully monitored and evaluated the completeness of the answer, so that even though the calculation is correct, the main supporting information to conclude whether it is cheaper or not is unclear. Meanwhile, from the metacognitive experience dimension, the student seems confident in solving the problem without any doubts in the process, but does not show reflective awareness that important information needs to be reaffirmed. This indicates that reflective experience of the thinking process has not been fully formed.

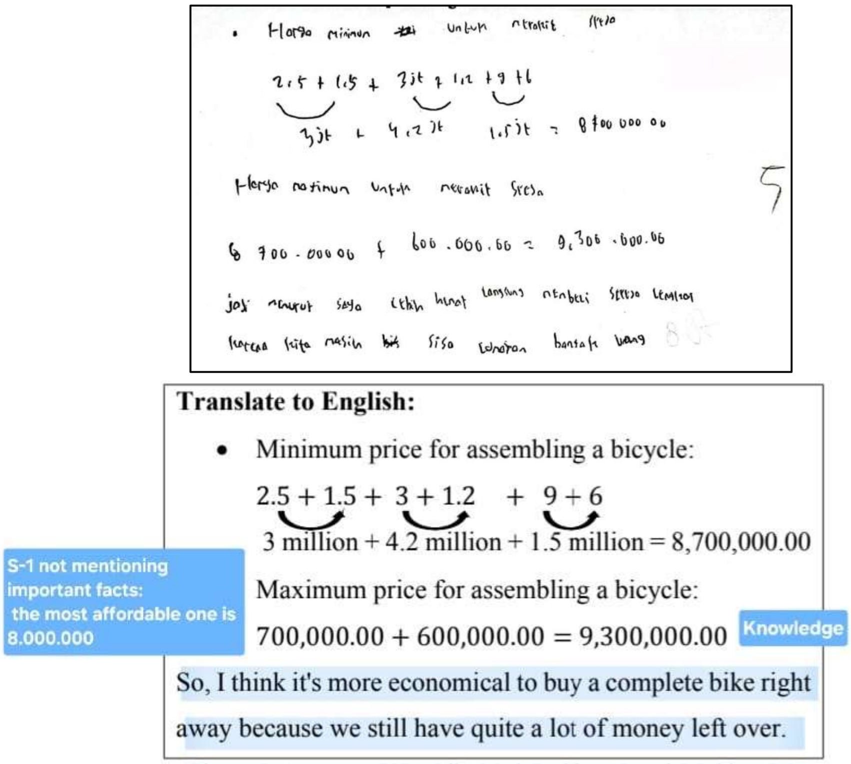
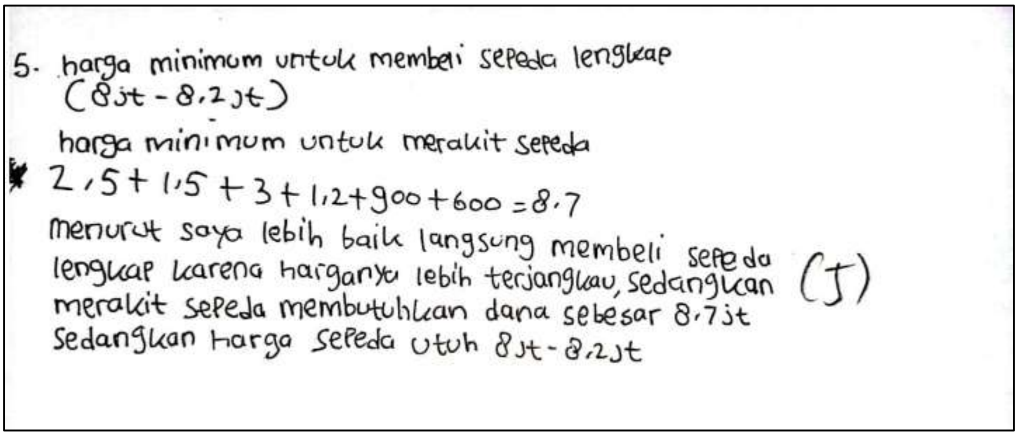


Figure 6. Answer to PISA-Like Math Problems Level 5 Subject S-1

Error Analysis of Subjects with Medium Mathematical Ability (S-2)

Figure 7 shows S-2's solution to the level 5 problem. In the handwritten answer, the student first writes *"harga minimum untuk membeli sepeda lengkap (8 jt – 8.2 jt)"* to note the price range of the complete bicycle. Next, S-2 calculates the minimum cost of assembling a bicycle by adding the lowest prices of the required components: $2.5 + 1.5 + 3 + 1.2 + 0.9 + 0.6 = 8.7$ million rupiah. At the end of the response, S-2 concludes that it is better to buy a complete bicycle because assembling one would require 8.7 million rupiah, whereas a complete bicycle costs only 8–8.2 million rupiah. The English transcription in the right panel conveys the same calculation and justification.

Student S-2 therefore does not experience metacognitive errors in this item, as reflected in his ability to understand the information given, perform the calculations correctly, and make a logical decision. He explicitly compares the minimum cost of assembling a bicycle (8.7 million) with the price range of a complete bicycle (8–8.2 million) and explains his choice with a clear economic reason. The decision to choose a complete bicycle because it is more affordable shows that S-2 is able to analyse the numerical data and draw a rational conclusion, so the answer is in line with the researcher's expectations.


5. harga minimum untuk membeli sepeda lengkap
(8jt - 8,2jt)
harga minimum untuk merakit sepeda
2,5 + 1,5 + 3 + 1,2 + 900 + 600 = 8,7
menurut saya lebih baik langsung membeli sepeda lengkap karena harganya lebih terjangkau, sedangkan merakit sepeda membutuhkan dana sebesar 8,7jt sedangkan harga sepeda utuh 8jt - 8,2jt (T)

Translate to English:

- Minimum price to buy a complete bike:
  (8 million - 8.2 million)
- Minimum price for assembling a bicycle:
  $2.5 + 1.5 + 3 + 1.2 + 900 + 600 = 8.7$

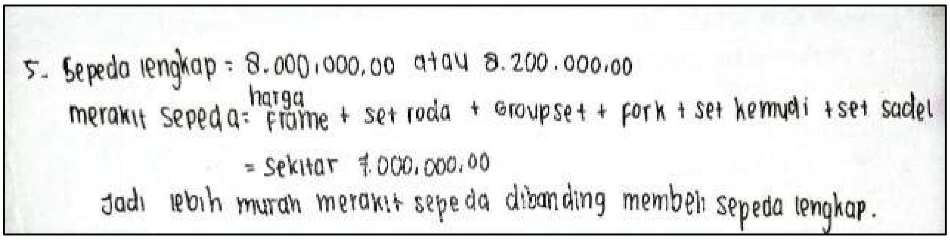
In my opinion, it's better to buy a complete bike because it's more affordable, whereas building a bike requires 8.7 million. Meanwhile, the price of a complete bicycle is 8 million to 8.2 million.

Figure 7. Answer to PISA-Like Math Problems Level 5 Subject S-2

Error Analysis of Subjects with Low Mathematical Ability (S-3)

Figure 8 shows S-3's written response to the level 5 problem. In the first line, the student writes the price of a complete bicycle as "8,000,000.00 or 8,200,000.00." On the next line, S-3 states the expression "frame + wheel set + groupset + fork + steering set + saddle set" as the components needed to assemble a bicycle, and then directly writes "= about 7,000,000.00" without showing any detailed addition of the listed prices. In the final sentence, S-3 concludes that assembling a bicycle is cheaper than buying a complete bicycle, solely on the basis of this approximate value. The English transcription in the right panel presents the same steps and highlights the generalised component expression and the rounded total of 7,000,000 as key indicators of the error.

This work indicates that S-3 experiences simultaneous weaknesses in metacognitive knowledge and metacognitive regulation. From the knowledge dimension, the student knows which components are needed conceptually, but does not demonstrate an accurate understanding of how to transform the price list into a concrete numerical model. The statement "about 7,000,000.00" suggests that S-3 relies on estimation without checking whether this estimate is consistent with the actual prices in the table. From the regulation dimension, there is no evidence that the student monitors or evaluates the process: S-3 does not write intermediate calculations, does not compare different combinations of component prices, and does not reconsider whether 7,000,000 is a reasonable total compared with the complete bicycle price of 8,000,000–8,200,000. This shows that the student skips important checking steps and accepts an initial intuitive estimate as correct, which is a clear form of metacognitive regulation error.


5. Sepeda lengkap = 8.000.000,00 atau 8.200.000,00
merakit sepeda = harga frame + set roda + Groupset + fork + set kemudi + set sadel
= sekitar 7.000.000,00
Jadi lebih murah merakit sepeda dibanding membeli sepeda lengkap.

Translate to English:

Complete bike = 8,000,000.00 or 8,200,000.00

Price of assembling a bicycle = frame + wheel set + groupset + fork + steering set + saddle set

= about 7,000,000.00 Regulative

So, it is cheaper to assemble a bike than to buy a complete bike.

Figure 8. Answer to PISA-Like Math Problems Level 5 Subject S-3

In the level 5 item, the pattern becomes more differentiated. S-1 showed errors in all three dimensions: knowledge (not explicitly stating the complete bicycle price as a comparison basis), regulation (not fully evaluating the completeness of the written explanation), and experience (solving the problem confidently without reflecting on missing information). S-2, by contrast, solved the problem correctly with a clear justification and showed no apparent metacognitive errors, indicating that his knowledge, regulation, and experience were aligned for this task. S-3 again exhibited both knowledge and regulation errors by estimating the assembly cost as "about 7,000,000.00" without detailed calculations and accepting this estimate without checking it against the given prices.

To make these patterns more visible, Table 2 summarises the presence of metacognitive errors for each subject and task level.

Table 2.
Summary of Metacognitive Errors by Subject, Task Level, and Dimension

Subject	Ability level	Problem level	Metacognitive knowledge error	Metacognitive regulation error	Metacognitive experience error
S-1	High	Level 3	No	Yes	Yes
S-2	Medium	Level 3	No	No	Yes
S-3	Low	Level 3	Yes	Yes	No
S-1	High	Level 5	Yes	Yes	Yes
S-2	Medium	Level 5	No	No	No
S-3	Low	Level 5	Yes	Yes	No

From Table 2 it can be seen that, in the level 3 problem, metacognitive regulation errors appear in all three subjects, while knowledge errors only appear in S-3. In the level 5 problem, regulation errors are found in S-1 and S-3, whereas only S-2 is free from errors in all three dimensions. Overall, regulation issues are the most frequent, followed by knowledge errors in low-ability students and, in some cases, high-ability students. Experience-related errors appear mainly in level 3, when students face unfamiliar representations and procedures for the first time.

The summary above shows that metacognitive errors are not confined to low-ability students. High-ability students such as S-1 also experience breakdowns, especially in the regulation and experience dimensions. This finding is consistent with Zhang et al. (2024), who report that even students with strong conceptual understanding may fail to organise and monitor their thinking processes, leading to incomplete or poorly justified solutions. However, this study adds nuance by showing that a high-ability student can carry out correct calculations yet omit crucial information (such as explicitly stating the comparison price) and still regard the answer as complete. In other words, strong mathematical knowledge does not automatically guarantee thorough metacognitive regulation in explaining and communicating solutions.

For medium-ability students, the results show a different pattern. S-2 demonstrates that when knowledge, regulation, and experience are aligned, students can solve complex contextual problems accurately and justify their reasoning clearly. At the same time, the earlier analysis of level 3 revealed that S-2 hesitated when dealing with decimal division but chose to continue without further checking. This echoes the findings of Riani et al. (2022), who note that at the junior high school level many students have reached the awareness stage of metacognition but still lack consistency in regulation and evaluation. The present study extends this by illustrating that such regulation lapses may disappear when the context is more familiar or when students feel more confident about the structure of the problem, as in the level 5 bicycle task.

Low-ability students, represented by S-3, show combined knowledge and regulation gaps across both problem levels. This aligns with Kusaka and Ndihokubwayo (2022), who found that students who do not habitually plan, monitor, and evaluate their solution steps tend to misapply basic concepts and accept unreasonable answers. In this study, S-3 not only misapplies percentage concepts (Level 3) and approximates costs without calculation (Level 5), but also fails to recognise that results such as 4560% or "around 7,000,000" need to be checked against the context. Compared with previous studies, the present findings highlight how conceptual weaknesses and regulatory failures interact: when basic concepts are fragile, students are less likely to question their own procedures and outcomes.

The interaction between problem level and ability level is also noteworthy. In level 3, which involves simpler computations but still requires interpreting a data table, all students make regulation-related errors. This suggests that the transition from routine textbook questions to contextual PISA-like tasks already challenges students' monitoring processes, regardless of their ability level. At level 5, which demands more complex modelling and decision making, high- and low-ability students diverge: S-1 can construct a correct cost comparison but fails to communicate all necessary information, whereas S-3 simplifies the situation too quickly by using rough estimates. This suggests that higher-level tasks exacerbate pre-existing differences: high-ability students may rely on intuition and skip explicit justification, while low-ability students may oversimplify the problem.

The results also resonate with (Reinhard et al., 2022), who argue that post-solving metacognitive reflection is effective only when students already have an adequate conceptual foundation. In this study, S-1 generally has strong conceptual understanding, so encouraging systematic reflection could help him notice missing information and refine his explanations. For S-3, however, reflection alone is unlikely to be sufficient; it must be combined with explicit support to reconstruct the underlying mathematical concepts. Thus, the study suggests that metacognitive instruction should be adapted to students' ability levels: high-ability students may benefit more from tasks that require explicit justification and cross-checking, while low-ability students need integrated support that simultaneously builds conceptual understanding and regulatory habits.

Overall, these findings support earlier work that emphasises the importance of metacognitive training in mathematics education (Kusaka & Ndihokubwayo, 2022; Riani et al., 2022; Zhang et al., 2024) but also add new insight by showing how specific types of metacognitive errors (knowledge, regulation, experience) appear differently across ability levels and task complexities. Strengthening students' metacognition therefore cannot be limited to introducing general problem-solving strategies or asking students to "reflect" at the end of a lesson. Teachers need to design learning activities that explicitly guide students to plan, monitor, and evaluate their thinking at each stage of solving contextual tasks like PISA, while at the same time addressing conceptual gaps that may prevent effective reflection.

Conclusion

This study demonstrates that eighth-grade students continue to experience metacognitive difficulties when solving PISA-like mathematics problems related to number content. Across both task levels, regulation errors were the most frequent, as students seldom monitored or reviewed their solution steps and often accepted numerical mistakes, incomplete justifications, or rough estimates without questioning them. Knowledge-related errors were primarily observed in low-ability students, and in some cases, even in high-ability students, revealing gaps in basic concepts such as percentages and ratios. Experience-related errors, on the other hand, emerged when students continued working despite feeling uncertain. These patterns highlight that procedural skill alone is not enough; students also need awareness and control of their own thinking processes.

The findings imply that metacognitive skills should become an explicit target of mathematics instruction so that students are better prepared for complex, real-world problems in PISA and national assessments, as well as for interpreting quantitative information in daily life. Teachers can support this by embedding prompts for planning, self-questioning, and error analysis into contextual and non-routine tasks. This research is limited by the small number of participants, one school context, and the use of only two PISA-like items, so the results are not meant to be generalised statistically. Future studies could involve larger and more diverse samples, explore other PISA content areas, and test classroom interventions that systematically train metacognitive regulation and reflection.

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