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## Exploring Students' Learning Strategies and Self-Regulated Learning in Solving Mathematical Higher-Order Thinking Problems

**Bansu Irianto Ansari**

Jabal Ghafur University,  
INDONESIA

**Muhamad Saleh\***

Serambi Mekkah University,  
INDONESIA

**Nurhaidah**

Syiah Kuala University,  
INDONESIA

**Taufiq**

Jabal Ghafur University,  
INDONESIA

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**Abstract:** Considering the low achievement of Indonesian students in international studies (PISA), which measures Higher-Order Thinking Skill (HOTS) in solving the problem, improving the quality of mathematics learning in Indonesia is very important. The purpose of this research was conducted to explore the variations in students' learning strategies and students' Self-Regulated Learning (SRL) in solving mathematical HOTS problems. The study employed a mixed-method, namely quantitative and qualitative methods were applied through five tests and seven interviews for over eight weeks. Two types of instruments were employed in this study, and they include tests and interviews. At the initial stage, we randomly selected 30 students from all those in grade 10 (Senior High School), after which 12 were chosen purposively after the pre-test for an interview, having satisfied all complete group, middle group, and lower group. All of them were treated using metacognitive questions. Data analysis techniques used were percentage, data reduction, presentation, and conclusion. The quantitative results showed the students could generally use orientation, organization, and elaboration learning strategies as observed with 68.3%, 60%, and 56.7% for complete, middle, and lower groups. Moreover, the students were also observed to have conducted three cognitive processes in selecting the rules for solving the mathematical HOTS problem, namely using models and drawing, written texts, and combining both. Furthermore, their final solution failures were affected by their misconceptions and errors in creating the mathematical model. The interview results on designing the learning procedures, monitoring the progress, and evaluating the outcomes, show that the students' SRL level is good for complete (89.3%), middle (75%), and lower groups (60.7%).

**Keywords:** *Learning strategies, SRL, HOTS, metacognitive question, misconceptions.*

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### Introduction

The recent change in operations due to the Industrial Age 4.0 has led to the demand for new working methods. There is, therefore, a need to design a long-term strategy for the national education system to produce students with competencies required in the future, such as creativity and critical thinking, mathematical reasoning, ICT, and collaboration skills (Ansari & Abdullah, 2020). Moreover, higher-order thinking and problem-solving abilities have been reported to be the skills needed to work in the 21st-century (Griffi et al., 2012). The competencies required by students in 21st-century learning also change. Previously students were only required to memorize concepts and understand them, now defines learning as an activity through which students personally construct their knowledge (Saleh et al., 2018). Therefore, learning at various levels has changed the teacher center's habits to become a student center (Quieng et al., 2015; Sharif & Cho, 2015). Demirhan (2014) argued that teachers play an essential role in developing and enhancing students' critical thinking skills. The basis of critical thinking skills is metacognitive skills. Both critical thinking and metacognition are associated with higher-order thinking (Fahim & Dorrmanesh, 2015). International contests as implemented by Organization for Economic Co-operation and Development (OECD) through the Programme for International Student Assessment (PISA) is a way to improve students' HOTS (OECD, 2014) because the industrial world requires it in the 21st-century. HOTS consists of solving problems, thinking critically and creatively, reasoning, and making decisions. These are part of the essential competencies required to be possessed by every student in the modern world (Widana et al., 2020). Therefore, it is necessary to train students on solving HOTS problems and reviewing their thinking strategies in solving problems.

\*Corresponding author:

Muhamad Saleh, Department of Mathematics Education, Serambi Mekkah University, Banda Aceh, Indonesia. ✉ [msalehginting@gmail.com](mailto:msalehginting@gmail.com)

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HOTS include the ability to analyze, evaluate, critical, logical, and creative thinking, problem-solving, decision-making, and meta-cognitive abilities (Aisyah et al., 2016; Yen & Halili, 2015). Furthermore, HOTS (1) is non-algorithmic, and this means its path of action is not fully specified in advance, (2) tends to be complicated, and (3) often yields multiple solutions, each with costs and benefits, rather than unique ones. These show the concept to be a complex thinking process requiring students to use brilliant non-algorithmic ideas in producing several solutions to problems (Resnick, 1987, as cited in Ansari & Abdullah, 2020). Therefore, this research focused on the thinking activities in the cognitive level of analysis, evaluation, creation, and Self-Regulated Learning in solving the mathematical HOT problem.

## Literature Review

### *Learning Strategies and Self-Regulated Learning (SRL)*

Gagne (1985) defined learning strategy as a cognitive strategy, namely the organization of intellectual skills by children to manage and organize concepts and rules. Kerlin (1992) viewed learning as a cognitive process influenced by individual circumstances, prior knowledge, attitudes, personal view, content, and presentation method. Cognitive skills help students to gain knowledge and to improve their intellectual abilities in the learning process and their learning experiences. The empowerment of cognitive skills will increase the students' ability to think about the results of the elaboration of their knowledge in learning (Fischer, 1998; Posthuma, 2015). This study using the term learning strategies to replace cognitive strategy with three indicators, namely (1) attention control, (2) information organization, and (3) knowledge elaboration. Attention control is the children's ability to focus their attention on certain problems in order to remember more relevant concepts.

The information organization is arranging all the information on the problem systematically; creating patterns and ideas as well as linking and applying them to solve problems. Knowledge elaboration is simplifying complex information through a model and applying correct rules for problem-solving (Gagne, 1985; as cited in Ansari & Sulastri, 2018). In this study, attention control is called orientation because it has the same characteristics, namely, remembering more concepts than required to solve the problem and presenting some alternative solutions before selecting the most accurate one. Information organization is called organization, and knowledge elaboration is called elaboration.

The behavior people display usually depends on their inner standards and their own motivation (Senemoglu, 2013). Self-regulated learning (SRL) is the degree to which students actively participate in their own learning in terms of metacognitive, motivational, and behavioral aspects (Zimmerman, 1990; Zimmerman & Schunk, 2001). Self-regulated learning in mathematics also has a significant role in adapting to learning in the new normal and influences students' mathematical learning outcomes (Pertiwi et al., 2021). Self-regulated learning includes how the behavior, motivation, and cognition directed towards students control a goal related to an academic issue. Therefore, Self-regulated learning is one of the crucial individual sub-factors contributing to learning (Eker & Aarsal, 2014). They identify their learning goal, observe the performance in accordance with the goal and regulate their cognition, motivation and behavior in order to attain the goal. Learning regularity is a recursive or repetitive cycle of cognitive activities involving analyzing tasks and selecting, adopting, or discovering strategies to achieve them as well as monitoring the outcomes (Butler, 2002). SRL involves three main phases; designing the learning, monitoring the progress while implementing the design, and evaluating the outcomes as a whole (Zimmerman & Schunk, 2001).

### *Metacognitive Questions and Misconception*

Several methods have been proposed for the teachers to improve students' reasoning when faced with HOT problems. One of them is IMPROVE, the acronym for Introducing new concepts, Metacognitive questions, Practicing, Reviewing, and reducing difficulties, Obtaining mastery, Verification, and Enrichment method. In the IMPROVE method, metacognitive questions are the main keys that must be presented by the teacher. Metacognitive skills are skills involving self-regulated ability, monitoring, and planning, self-assessment of the learning strategies used, the effectiveness in the problem-solving process faced (Kramarski & Mizrachi, 2004; Veenman et al., 2006). Metacognition leads to higher-order thinking skills that involve active control of certain cognitive processes in learning (Howard, 2004; Kozikoglu, 2019; Uzuntiryaki et al., 2013; Willingham, 2007). Thus, students need to have the metacognitive skill as a key for improving their thinking capacity (Kozikoglu, 2019; Tan, 2004).

Metacognitive questions include four questions namely (1) Comprehension questions, that encourage the students to read the problems, describe the concepts in their own words, and try to understand the meaning of a concept. Such as: "what is the overall problem about?" (2) Connection questions that encourage students to see the similarities and differences in a concept/problem, such as: "what are the similarities and differences between the current and previous problems?" (3) Strategy questions, that encourage students to consider appropriate strategies to solve the problems appropriate for solving the problem?" (4) Reflection questions that encourage the students to ask themselves about the problem-solving process, such as: "What am I doing?" (Kramarski & Mizrachi, 2004). The misconception is related to the irregularity of learning as students are less familiar with solving the teacher's exercises. Such as the students solve the problem, how students organize their learning strategies using connection

questions. The misconceptions occurred when they see the similarities and differences in a concept/problem. In this study, misconceptions are checked from the error of the design Geometry drawing and creation of the model.

Several studies have been recently conducted on HOTS, Metacognitive Strategies, and Self-regulated Learning. Such as in the Muhammadiyah University, that mathematics education students' HOT ability to analyze, evaluate, and create from the first to the second cycle through a Project-Based Learning model in Advanced Calculus was showed a significant increase (Akhsani & Purwanto, 2014). Buku et al. (2016) conducted a study about the correlation between Metacognitive Skill and Critical Thinking Skills, showed that there was a correlation between metacognitive skill and critical thinking skills of class X and XI students with the regression equation of the two variables  $y = 1.1775x - 0.0295$  having a contribution value of 90.80%. Then Pertiwi et al. (2021) about Mathematical Problem-Solving Abilities (MPSA), Self-Regulated Learning (SRL), and VBA Microsoft Word in New Normal: A Development of Teaching Materials. The method used in this research is an experimental method with a pretest-posttest control group design. This study indicates that VBA Microsoft Word-based teaching material is appropriate to be applied in the new normal period, as indicated by the results of the achievement and improvement of MPSA and SRL of students is better than ordinary learning. There is an association between MPSA and SRL and positive response even though they still have difficulty making mathematical models on MPSA questions. However, this current research is different from those previously described in purpose, the number of variables, research design, method, and the approach adopted for analysis.

Based on the above, the purpose of this study was to explore and describe the variations in students' learning strategies and Self-Regulated Learning in solving mathematical HOT problems, based on the problems as follows:

1. What are the students' learning strategies in solving mathematical HOT problems?
2. How do students manage their learning process to solve mathematical HOT problems?
3. How can the interview results be converged/ combined to enrich the interpretation of the student's assessment score? (Mixed-quantitative and qualitative)

## Methodology

### *Subjects and Sampling Procedure*

This research was conducted at an A-accredited Senior High School in Banda Aceh in 2019/2020. The students were observed to have homogeneous abilities without any discussions regarding how to solve HOT problems found with their teachers. A sample of 30 students was selected randomly from all those in grade 10 and aged 15-16. Moreover, the pre-test consisting of HOT problems was followed by interviews after which 12 students were purposively selected for further investigation out of which 4 were observed to have satisfied all the indicators of learning strategies (Complete group), 4 fulfilled some (middle group), and another 4 was able to meet just one (lower group). The selection process is presented in Table 1.

*Table 1: The Subject election procedure*

Student category	Number of questions and number of students			The average number of students (Purposive)	Number of subjects (Randomly)
	1	2	3		
Complete	4	4	4	4	4
Middle	16	18	17	17	4
Low	10	8	9	9	4
Total	30	30	30	30	12

### *Research Design*

The study employed mixed methods, namely quantitative and qualitative approaches, with concurrent embedded strategy, to use both primary and secondary methods simultaneously. The primary process involves retrieving the data while the second one focused on gathering supporting data, and they were both analyzed (Creswell, 2010). The first stage involved using a quantitative approach while the second was conducted qualitatively, and they both produced the results for this study. The quantitative method was designed to describe students' reasoning skills based on the initial, benchmark, and final tests while the qualitative showed the selected students' cognitive strategies skills connected with Self-Regulated Learning via the interviews. Data were collected at four measurement time points, analyzed separately, and the results were merged into two strands to determine the points where the interview data converged with, diverged, or augmented the test score data (Creswell & Plano Clark, 2011). The dialectics perspective was intentionally applied to investigate both the divergences and convergences between the data sets (Shannon-Baker, 2016). Moreover, the mixed-method design flow is presented in Figure 1 was adapted from the design used in (Plano Clark et al., 2015).

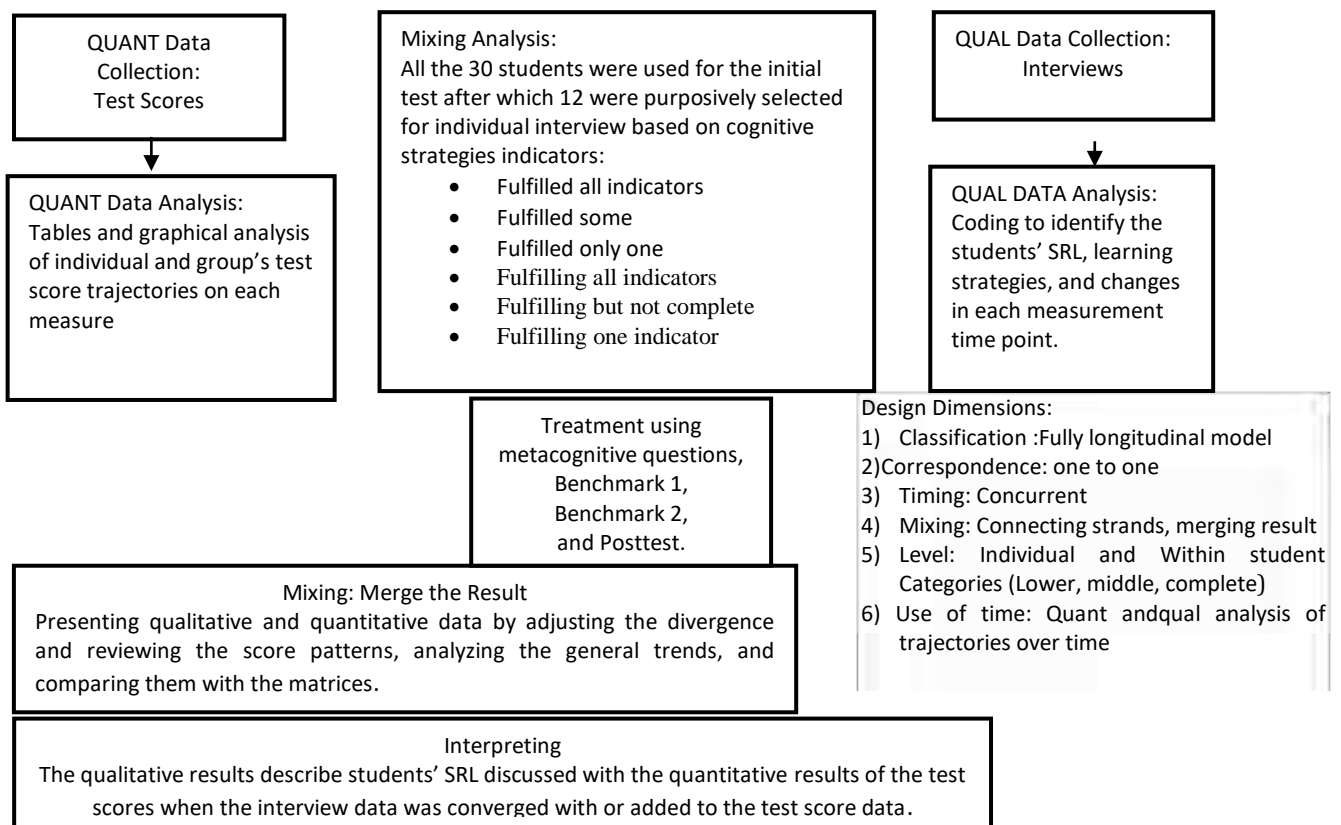


Figure 1. Flowchart of the research

### The Procedure of Data Collection

The research started by carrying out the procedure as follows:

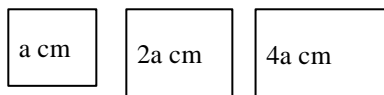
1. Conducting a pretest on 30 students to be selected 12 students who will be the sample subjects. For analysis purposes, they were divided into three groups (see table 1).
2. Conducting treatment for 30 students, namely training them to solve HOT problems using metacognitive questions as previously mentioned. Students work in heterogeneous groups of two to five students. They were asked to solve the problems in the student worksheets with the help of four metacognitive questions. Then the teacher guides the students to explain, summarize, or reflect. Data were collected for eight weeks, including pretest at week 0, benchmark 1 at week 3, benchmark 2 at week 5, and posttest at week 8.
3. The material of posttest was Geometry with five Higher Order Thinking (HOT) problems in the form of mathematical reasoning consist of (1) propose predictions or conjecture, (2) provide reasons for the answers, (3) find patterns of a problem, (4) examine the validity of an argument, and (5) draw conclusions from a statement (Kilpatrick et al., 2001). Then analyzed the strategies used by the students in solving the problems, namely three learning strategies identified were (1) Orientation, (2) Organization, and (3) Elaboration.
4. After that, the researcher conducted interviews with 12 students who had been selected as sample subjects with seven questions on designing the learning procedures, monitoring the progress, and evaluating the outcomes categorized their Self-Regulated Learning (SRL). This was followed by triangulating the source to examine the validity of the data obtained in the final test results, namely comparing the results of the final test with the results of interviews.

### Data Analysis Techniques

Two types of instruments were employed in this study, and they include tests and interviews. Mathematical HOT tests were administered to examine students' learning strategies, with the final one consisting of five items designed to meet the five indicators of mathematical reasoning ability previously mentioned. They were all tested for validity and reliability. Meanwhile, structured interviews were conducted to investigate the factors influencing students' learning strategies regarding the methods they apply in organizing the learning process. The main concern was not to determine if the final results were correct but rather on the process of achieving the results. Quantitative data analysis was a percentage and qualitative data analysis was conducted in several stages, namely data reduction, data presentation, and conclusions (Miles & Huberman, 1994). Data from the interview results are reduced to obtain the necessary statements in accordance to be achieved, the following of the post-test and interview list.

1. The increase in volume as the circular cone radius increased by 24 cm is equal to the increase in volume when the height of the cone increased by 24 cm. If the initial height is 3 cm, determine the initial radius. How do your predictions this answer? Please check!
2. Both ABCD and PQRS are congruent cones. The base radius and the height of the ABCD cone are a cm and b cm, respectively. While PR = 2 AC, height RS = x cm.
  - 1) Investigate whether  $x = 2b$ ? and  $QS = 2a$ ?
  - 2) Investigate whether the volume of the bigger cone is two times that of the smaller one. Provide your reasoning!

3. Look at the patterns of rectangles below:



123

If the area of the second rectangle is  $1000 \text{ cm}^2$ ,  
What is the area of the  $n^{\text{th}}$  rectangle?

4. A right triangle ABC, right-angled at A, and therefore  $BC^2 = AC^2 + AB^2$ . Is the conclusion of the statement correct? Given your reason.
5. Given that a cube of ABCD.EFGH,  $B_1$  is the sphere outside the cube, and  $B_2$  is the sphere inside the cube. Suzan has calculated that the comparison of the  $B_1$  and  $B_2$  is  $2\sqrt{2} : 1$ . What is your opinion, is it right? Please check!

There are seven questions in the interview based on (Zimmerman & Schunk, 2001), they are:

1. Designing the learning:
  - How many hours do you study in a day?
  - Do you specify the study time?
2. We are monitoring the learning progress while implementing the design.
  - Do you do the posttest given by the teacher?
  - How do you select formulas and organize problems?
3. Evaluating the learning outcome as a whole:
  - What are the learning strategies you used in solving the problem?
  - When you experience difficulties, do you look for the textbook's solution, ask your friends or wait for them to be discussed in the classroom?
  - Do you have a target to solve the problem? Do your parents care about your school task?

To determine students' learning strategies in solving the HOT problem, a test instrument consisting of 5 items was presented. Each item developed has a score of 0-100. The learning strategies characteristic and the rubric of SRL used in this instrument can be seen in the table below.

Table 2. Learning Strategies Characteristic (Ansari & Sulastri, 2018)

No	Aspect	Characteristic
1.	Orientation	- Remembering more concepts than required to solve. - Presenting some alternative solutions before selecting the most accurate one
2.	Organization	- Arranging all the information on the problem systematically. - Creating patterns and ideas as well as linking and applying them to solve problems.
3.	Elaboration	- Knowledge elaboration is simplifying complex information through a model. - The ability to apply correct rules to solve certainly problems.

Table 3. *Self-Regulated Learning and scoring rubrics of the study*

No	Self-Regulated Learning	Good	Poor	
1.	Designing The Learning	How many hours do you study in a day?	Two hours or more	No
		Do you specify the study time?	Yes	No
2.	We are monitoring the learning progress while implementing the design.	Do you do the posttest given by the teacher?	Yes	Sometime or NO
		How do you select formulas and organize problems?	Using drawing and Math expression	Trial and error
3.	Evaluating the learning outcome as a whole:	What are the learning strategies you used in solving the problem?	Orientation, organization, or elaboration	Trial and error
		When you experience difficulties, do you look for the text book's solution, ask your friends or wait for them to be discussed in the classroom?	Learning solution in a text book or ask your friends	Wait for the teacher's solution
		Do you have a target to solve the problem? Do your parents care about your school task?	Yes	No

#### *Validity and Reliability*

In this study, the validity test used Pearson Product Moment and reliability was the Cronbach's alpha declared. The significance level used is 0.05 for the validity and reliability test. After all, items are declared valid and reliable in this study, and then the instrument is given to students. The result of the validity test can be said to be valid if the Pearson correlation > r table. Meanwhile for reliability tests are using SPSS can be said high-reliability category (.805). The validity can be seen in the table.

Table 4. *Results of testing the validity*

No item	Pearson correlation	R table (n = 6/sig level = 0.05)	Category
1	.898	.015	Valid
2	.986	.000	Valid
3	.784	.065	Valid
4	.866	.026	Valid
5	.693	.127	Valid

#### **Results**

The study was conducted to explore the variations in students' learning strategies and Self-Regulated Learning to solve mathematical HOT problems. The results are reported under four main headings which are 1) Variations in students' paper-pencil assessment especially in using the learning strategies, 2) Variations in students' interview, 3) Variation in students' trajectories in term of students' increase or decrease in scores and strategy in term of their pretest, and 4) Determining the variation in students' cognitive process while solving the problem. The first section focuses on the tables and graphs of students' learning strategies tendencies or quantifying the variation in students' scores. The second section presents and describes the interview analysis of the variation in students' strategies to solve HOT problems and their Self-Regulated Learning. These were followed by interpreting the data based on the learning strategies associated with the students' approach towards the organization of their learning process and the misconceptions observed while solving the problems. The third and fourth sections present the results and interpretation of the variation in students' trajectories in terms of overall themes in the convergence or divergence of data and students' increase or decrease in scores using mixed analysis.

*Variations in the use of learning strategies element**Table 5. Recapitulation of Students' Learning Strategies in the posttest*

Number and problems Type	Elements of Learning strategies	Students Categories			Total number of student in the posttest
		Complete N = 4	Middle N = 4	Lower N = 4	
1. Conjecture	Orientation	1	-	1	2
	Organization	3	3	2	8
	Elaboration	4	3	4	11
2. Reasoning	Orientation	-	1	-	1
	Organization	2	3	3	8
	Elaboration	4	4	4	12
3. Pattern	Orientation	2	-	1	3
	Organization	3	3	3	9
	Elaboration	4	3	4	11
4. Validity	Orientation	2	-	2	4
	Organization	2	-	4	6
	Elaboration	4	4	4	12
5. Conclusion	Orientation	2	3	2	7
	Organization	4	2	3	9
	Elaboration	4	2	1	7
Total		41	31	38	110

Based on Table 5, the frequency tables concerning the use of elements of the student's learning strategies (orientation, organization, and elaboration) based on the type of problems, groups, and percentages are presented in Tables 6.

*Table 6. Frequency in the use of the student's learning strategies.*

Percentage of Learning Strategies	Students											
	Complete				Middle				Lower			
	TG	ZA	BC	CT	RH	DA	SH	AA	HS	PA	RF	SA
Orientation	1	3	1	2	2	1	-	-	3	1	2	1
	20%	60%	20%	40%	40%	20%			60%	20%	40%	20%
Organization	1	4	4	5	1	4	5	5	1	4	2	4
	20%	80%	80%	100%	20%	40%	100%	100%	20%	80%	40%	80%
Elaboration	5	5	5	5	5	4	4	4	5	3	4	4
	100%	100%	100%	100%	100%	80%	80%	80%	100%	60%	80%	80%
Total	7	12	10	12	8	9	9	9	9	8	8	9
		41				35				34		

Interpreting the data based on the table shows the percentage of learning strategies, including orientation, organization, and elaboration used by each student is interpreted as the ability. For example, for ZA, the orientation percentage used in relation to the number of problems was 3 times (60%), and this means the student's ability is 60. Furthermore, the organization percentage used in relation to the number of problems was 4 times (80%) and this means the student's ability is 80, and the elaboration percentage used in relation to the number of problems was 5 times (100%), and this means the student's ability is 100.

*Graph of Learning Strategies Tendencies*

Based on Table 6, we can observe that for the group of students fulfilling all indicators (complete), the percentage of the learning strategy of orientation, organization, and elaboration used in relation to the number of problems is 35, 70, and 100 respectively. The group's ability to fulfill some of the indicators (middle) in using the learning strategies is 15, 75, and 90 accordingly while the group's ability fulfilling one of the indicators (low) is 35, 55, and 80. The following graph illustrates each learning strategy's trends based on students' groups represented in the following Figure 2.

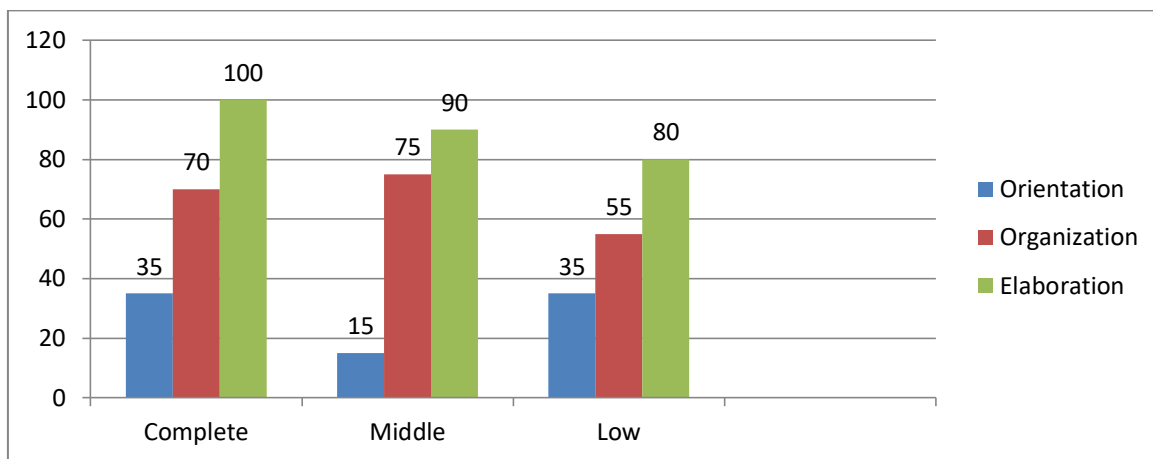


Figure 2: Graph of Learning Strategies Ability

### Variations in students' interviews

The interview was conducted for the students after the post-test was analyzed. The purpose was to associate it with students' learning strategies and the cognitive process with their Self-Regulated Learning based on (Zimmerman & Schunk, 2001).

To illustrate some of the conditions, further interviews are conducted against the three students are:

#### 1. Student ZA

T: How many hours do you study in a day?

S: 2 hours.

T: Do you specify the study time?

S: Yes, if there is a difficult question.

T: Do you do the post-test given by the teacher?

S: Of course, I did it.

T: How do you select formulas and organize problems?

S: Trying to remember the relevant formulas and compiling information about the question.

T: What are the learning strategies you used in solving the problem?

S: Trying to understand the questions first and then finding the formula that is relevant to the questions, the next is creating equations and doing calculations.

T: When you experience difficulties, do you look for the textbook's solution, ask your friends or wait for them to be discussed in the classroom?

S: Trying to do it myself first, then asking friend, but if I could not find any solution I will ask my teacher.

T: Do you have a target to solve the problem? Do your parents care about your school task?

S: Yes, I have my own target to finish it. My parents do care about my homework.

#### 2. Student DA

T: How many hours do you study in a day?

S: It depends on the situation.

T: Do you specify the study time?

S: No.

T: Do you do the post-test given by the teacher?

S: Yes, the one that I can do.

T: How do you select formulas and organize problems?

S: Choose the formulas that are relevant to the questions.

T: What are the learning strategies you used in solving the problem?

S: Reading the questions carefully, then drawing a picture and calculating it.

T: When you experience difficulties, do you look for the textbook's solution, ask your friends or wait for them to be discussed in the classroom?

S: I am waiting for the teacher to discuss problems that I cannot solve.

T: Do you have a target to solve the problem? Do your parents care about your school task?

S: The target is to answer the questions, although I should discuss it with my friends and my teacher. My parents always ask if there is any homework. If yes, they suggest me to finish it soon.



## 3. Student PA

T: How many hours do you study in a day?

S: Uncertain.

T: Do you specify the study time?

S: Sometimes, when I got homework from the teacher.

T: Do you do the post-test given by the teacher?

S: Yes, but I copy-paste my friends work.

T: How do you select formulas and organize problems?

S: I try to choose the formula randomly.

T: What are the learning strategies you used in solving the problem?

S: Modelling it, and choose the right formula.

T: When you experience difficulties, do you look for the textbook's solution, ask your friends or wait for them to be discussed in the classroom?

S: Sometimes discuss with friends and also teachers in the school.

T: Do you have a target to solve the problem? Do your parents care about your school task?

S: Sometimes, I could not finish the problems, and some answers are incorrect. My parents seldom ask me about my homework.

Table 7. Determining of students' SRL levels

Students	Category	Good	Poor
Complete	TG	7	-
	ZA	7	-
	GC	5	2
	CT	6	1
	Percentage	25 (89.3%)	3 (10.7%)
Middle	RH	6	1
	DA	5	2
	SH	5	2
	AA	5	2
	Percentage	21 (75%)	7 (25%)
Lower	HS	5	2
	PA	3	4
	RF	5	2
	SA	4	3
	Percentage	17 (60.7%)	11 (39.3%)

The interview showed students with high parental motivation, including TG, ZA, and CT from the complete group and DA, RH from the middle group, always do the homework due to parents' attention and motivation to succeed. This further indicates the parental role's dominance in supervising the children while working on the school assignment. The full interview results showed the students' Self-Regulated Learning (SRL) were categorized as good with 89.3%, 75%, and 60.7% for the complete, middle, and lower groups, respectively, as shown in the relationship between students' SRL and other variables influencing learning process in Table 8.

Table 8. Relationship between Self- Regulated Learning and other variables

Student	Cognitive process in solving of HOT problems						Misconception	SRL		Learning strategies
	model/ drawing		written texts		combination			Good	Poor	
	true	false	True	False	true	false				
Complete	80%	20%	75%	25%	75%	25%	23.3%	89.3%	11.7%	68.3%
Middle	59%	41%	35%	65%	30%	70%	58.7%	75%	25%	60%
Lower	50%	50%	18%	82%	15%	85%	72.3%	60.7%	39.3%	56.7%

The table shows Self- Regulated Learning, misconception, and errors in arranging models and drawing are interrelated. The students observed learning less regularly experienced the misconceptions on average with 72.3% followed by errors in arranging models and images with 50%. Meanwhile, those learning were periodically reported to have only 23.3% and 20%, respectively. This conceptually means the students' failure in the final solution was due to their misconceptions and errors in modeling and drawing, especially due to learning irregularity. They are less familiar with the solutions to the teacher's exercises.

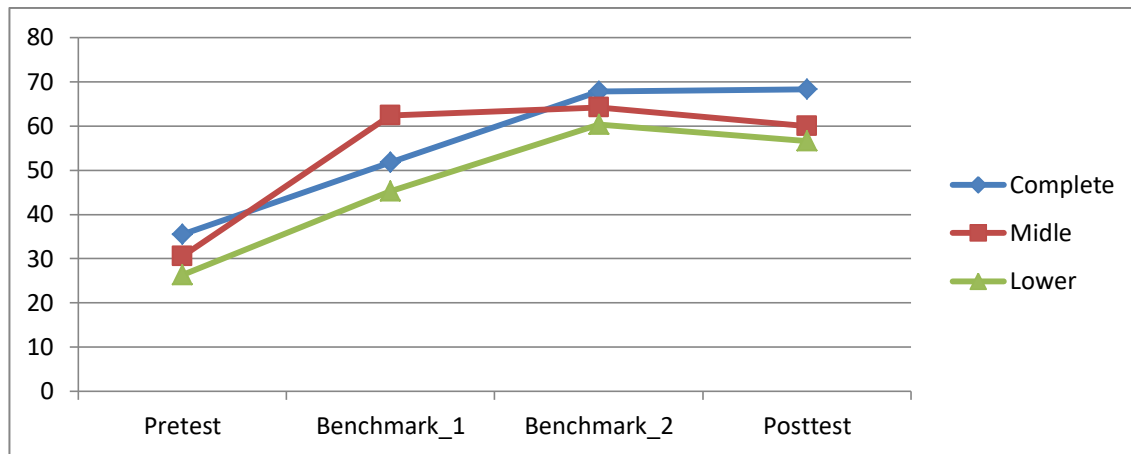
*Variation in students' Trajectories*

Figure 3. Variation in students' HOT problem assessment scores.

Figures 3 and Table 9 display a score trajectory based on four measurement points and present the score chart for each student to measure the mathematical HOTS skills. DA was observed to have shown the continuous increase in the effects up to 80% in the final score, ZA also had a consistent rise in the score at each assessment point, GC and ZA showed a steady increase in the mathematical HOTS ability scores while AA and PA had an increase in scores at the initial stages but a decrease in the final stages.

Table 9. Matrix of the Patterns for HOTS Problems Scores.

Students Category	Student	Increasing	Peak and decreasing	Flat	Total
Complete	ZA, GC, CT, TG	ZA, GC, CT	0	TG	4
Middle	SH, AA, DA, RH	SH	AA	DA, RH	4
Lower	RF, SA, PA, HS	RF, SA	PA	HS	4
	Total	6	2	4	12

## Discussion

### *Determining the variation in the students' learning strategies and misconception*

The students' paper-pencil assessment analysis presented in Table 6 and Figure 2 shows the students' ability in using learning strategies vary widely, with those using orientation, organization, and elaboration recorded to be 68.3%, 60%, and 56.7% for the complete, middle, and lower group, respectively. This indicates the metacognitive questions trained on the students to solve HOTS questions during the treatment were not optimal. This finding differs from Baltaci et al. (2016) that metacognitive strategies and learning styles can improve fifth graders' mathematics grades. This is associated with reviewing the sample subjects using gender, while Ansari and Sulastris' (2018) study did not. However, the students could use three cognitive processes to select the rules to solve the problems. This involved using models and images through mathematical expression and drawing, forming patterns and connecting ideas through written texts, and combining both. The selection of these rules depends on the students' ability to make connections between concepts. Moreover, the Models and images used to tend towards the elaboration learning strategy, the patterns, and ideas were formed with an inclination towards the organization strategy, while the combination of both processes also used the two strategies.

Of the 12 students being studied, seven students were dominant in the element of elaboration learning strategies, three in the organization, two in the orientation, two in both orientation and organization, five in both elaboration and organization, and two in both orientation and elaboration. Of the seven students who were dominant in the use of cognitive elaboration strategy, four were those who satisfied all indicators of the learning strategies in the pretest and two were from the middle group, and one was from the lower group. Meanwhile, of three students tending to use the organizational learning strategy, two were from the middle group, and one was from the complete group. Most students who were dominant in the orientation strategy were the lower group.

Students with orientation learning strategy performed better in solving problems related to validity, those with organizational ability addressed exercises related conclusions effectively, those that combined both strategies were able to solve the problems regarding patterns and reasoning, while those with elaboration were able to attempt problem two.

The results showed students with elaboration learning strategy tendencies were more likely to succeed than others. However, only 2 out of 6 students achieved the final solution conceptually, 3 were classified under the successful category ( $x > 75$ ) while the remaining 1 experienced misconception.

Furthermore, 3 out of 6 students were inclined to elaboration learned regularly and reached 100% using the strategy. This, therefore, means regular learning strengthens the concept of the cognitive structure due to the addition of new related concepts in each learning. This process of acquiring knowledge lasts for a long time due to its relationship with the previous ones. Meanwhile, the misconception and errors in creating the mathematics model and image were the main contributing factors observed for the student's failure in the final solution. The models presented were observed to have deviated from the geometry rules, incorrect, and the steps used were conceptually false. This, therefore, indicates the interrelationship between the learning regularity, misconception, and errors in creating the model. The results showed students with irregular study methods had an average of 72,3% and 50% for misconceptions and errors, respectively. This Phenomenon is also mentioned by Zimmermann (1990) that there is a direct link between self-regulation strategies and academic success.

The student's failure to present the final solution conceptually was affected by the misconceptions namely error of the design 3D Geometry image and errors they experienced while creating the mathematics model and drawing. This is causing the loss of mathematical concepts learned previously. As a result, students who achieve poor results are likely to hold high anxiety. Mathematics anxiety is one's attitudes showing fear or nervousness in solving mathematics problems or mathematics learning, so the students are less accustomed to solving the teacher's exercises (Ansari & Wahyu, 2017). Therefore, as instructors and facilitators, teachers need to select the appropriate learning approach and look carefully at students' abilities to minimize errors (Saleh et al., 2019).

#### *The Tendency of Orientation Learning Strategy*

The results showed, 8 students used an orientation learning strategy to solve mathematical HOT problems. As previously discussed, this strategy is mainly applied by lower group students because they have unconnected information based on their limited knowledge. However, they managed to use the elaboration strategy through drawing even though it was less predictive in determining the next step, thereby, causing difficulty for the students in selecting rules to reach the final solution due to the inability to connect to the existing concepts. In these circumstances, students conduct trial and error by matching some formulas to the problem's information. The final method is not within the students' powers, which means they cannot justify the accuracy of their final results since they do not have a conceptual understanding of the process of the formula applied.

Some students failed to solve the problems due to misconceptions, especially those associated with not using the mathematics model. Many symbols in solid geometry are similar, for example, the sides in it indicate plane or area while those in plane geometry mean edge or length, and several students misunderstand these due to their failure to use the model. Some of the students used in this study experienced RH, DA, SH, CT, HS, DA, and solving the fourth and fifth problems. One effort to correct the students' conception of the unit is by providing clear information on the distance and angle in solid geometry and intensive discussion of problems or homework with the teachers. These results are in line with the findings of Nalurita et al. (2013), which showed that students experiencing misconceptions are majorly those with low mathematical abilities, leading to their lack of analytical, evaluation, and creation to be high thinking order skills.

Applying metacognitive questions to rectify the misconception based on its advantages associated with reflecting on the cognitive processes used is possible. This, therefore, means metacognition can be interpreted as a person's thoughts about its thoughts or cognition about its cognition (Schoenfeld, 2006). The students are expected to rectify the conception while engaged in the process. Moreover, another method is by using the "conflict-cognitive" approach, which provides "new meaning" to contradict the "old meaning" to be corrected through a process of active engagement and applying the method understood by the students. This is called accommodation and has been labeled a conceptual exchange (Hewson & Thorley, 1989). According to Purnomo et al. (2017), the three metacognitive processes in solving problems include planning, observing, and evaluating, and since these are associated with high-level thinking activity, a metacognition step is very important in finding solutions to mathematical problems.

#### *The Tendency of Elaboration-Organization Learning Strategies*

The elaboration-organization trend was deliberately presented due to the limited number of students using it as observed in its application by some high-achieving students in the complete group to solve problems 1, 2, 3, and 5. This was reported to have been conducted in two ways, including selecting rules by either elaboration or organization as discussed in sections a and b while those considered unsuccessful employed the information in the problem as a tool to select the rules.

The students initially created a drawing and then arranged the mathematics model, but they found it challenging to work further since the image was less helpful in determining the subsequent steps. They later tried to rearrange the information in the problem and apply their problem-solving pattern, which is sometimes far from the problem's

circumstances but adequate to guide the solution. An example of this is indicated by TG's approach towards checking the accuracy of problem 1. This involved organizing the knowledge by arranging smaller sets and systematically determining all the information in the problem. A model of the subset was created, and the final solution was determined even though it was incomplete. The previous two strategies applied are seen as the verification step which indicates the students oversaw the problem-solving steps and after experiencing difficulties or irregularities, they use other methods instead of proceeding.

The students with the elaboration tendency remember knowledge as the package enabling them to retain a lot of related information quickly, and this has been observed to be a powerful means to analyze and solve problems and also serves as an advantage over other strategies. Those that applied orientation strategy were observed not to analyze conceptually but follow the pattern of the previous problem, and when they were faced with new ones, they struggled to solve them. The ability to elaborate and organize is a HOTS ability and a person's creativity. This phenomenon is in line with the opinion of Widana et al. (2020) that, understanding the HOTS concept has a direct positive effect on creativity.

Furthermore, Figure 3 and Table 9 display the matrix based on the pattern in the line graph for the magnitude of the mathematical HOTS test score using the pre-test, and the results showed ZA, GC, and CT scores in the complete category increased in the four measurement time points. In contrast, DA and SH in the middle category and SA in the lower category were initially low but risen later in the next measurement point. Meanwhile, AA and PA in the middle and lower categories had a similar score trajectory that initially increased and later decreased. However, the scoring pattern to measure the mathematical HOTS in the pre-test was not consistent with the next three tests. Especially for low-ability students, the teacher's role to involve students in the problem-solving process is very important. Because the creativity of the teacher in compile HOTS questions according to the needs of students is very necessary (Widana et al., 2020).

### Conclusions

The paper-pencil assessments used as the primary data sources for the quantitative analysis showed the students' ability to use orientation, organization, and elaboration learning strategies varied significantly. Those in the smart or complete group were observed to have used elaboration dominantly, middle groups applied organization while those in the low group mostly used orientation strategies to solve HOTS problems. Three cognitive processes were used to select the rules to solve the problems. They include using models and images, forming patterns and connecting ideas through written texts, and combining both selected based on students' ability to connect the concepts. Qualitatively, the interviews showed Self-Regulated Learning (SRL) was categorized as well based on five questions asked, and the smart or complete group was found to have more than the others by using images, forming patterns, and connecting ideas to select formulas and organize the problems. The results also indicate the regularity of learning, misconception, and errors in arranging drawings and models are interrelated. A very high misconception indicated this and errors in organizing drawing and models experienced by students who learned less regularly. These were conceptually associated with the failure in their final solution. Meanwhile, those learning regularly were reported to have averagely low misconceptions and errors. Furthermore, a variation was also observed in solving the HOTS problems as the students' interview data were found to have converged with, diverged from, or augmented their assessment data. This provided further insight into each student's posttest over the eight weeks. For example, there were no differences in TG strategies on both the pretest and middle test, but there was an improvement in the assessment scores over the post-test eight weeks. Moreover, PA's assessment scores also dropped at the posttest measurement point. Still, they improved in the middle scores test, and the interview results associated this trend to her parent's attention to the completion of homework and school assignments. Finally, based on these findings, the role of teachers is very important in increasing student HOTS. The teacher must always involve students in the learning process, especially in solving HOTS problems.

### Recommendations

It is suggested that teachers can strive to improve the quality of students' reasoning through solving mathematical HOTS problems. Therefore, the teacher's effort to improve the competence on mathematics HOTS-based assessments, it can be done through training. Furthermore, the students' interview revealed that students with a high parental motivation always do the homework due to parents' attention and motivation to succeed.

### Limitations

In general, research is limited to its methodology, which is not comparing the pretest and posttest scores because it does not have an interval score, but only has a nominal score of orientation, organization, and elaboration abilities. Then the data analysis used percentages, did not perform statistical tests on students' scores from the complete, middle and lower groups.

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