



# Explore Students' Metacognitive Thinking Process in Solving Compound Polarity Problems Based on The Level of Academic Ability

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Received: June 15, 2023

Revised: September 5, 2023

Accepted: November 25, 2023

Published: November 30, 2023

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DOI: [10.29303/jppipa.v9i11.4293](https://doi.org/10.29303/jppipa.v9i11.4293)

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**Abstract:** This study was designed to identify and describe students' metacognitive thinking process in solving compound polarity based on academic ability level. Two hundred and eighty-four high school students in Indonesia participated in the study. Students are classified into high, middle and low academic ability groups based on field notes, student academic data, compound polarity problem-solving test (CPPST) scores and teacher suggestions. Six selected students from each group were designated as research subjects and then interviewed in depth to explore their metacognitive thinking processes. CPPST answer sheets and interview transcripts were analyzed using summative content analysis and tested for validity by data triangulation. The results showed that the students with high and medium academic ability level carry out metacognitive thinking processes in the dimensions of planning, monitoring and reflection in solving compound polarity problems, where the metacognitive thinking processes of students with high academic ability are more varied than students with middle academic ability. Students with low academic ability only carry out the dimensions of planning and monitoring. Therefore, teachers need to train students' metacognitive skills in solving problems and get used to applying metacognitively in each given problem solving so that students are trained to solve problems systematically, carefully and thoroughly, and manage time properly in order to obtain the expected learning achievement.

**Keywords:** Academic ability level; Compound polarity; Metacognitive; Problem solving; Thinking process

## Introduction

The 21st century learning paradigm emphasizes students' ability to think critically and creatively, be able to apply knowledge in the real world, master technology and information, communicate and collaborate. Students are directed to be able to access information effectively and efficiently, evaluate information that will be used critically and competently, use and manage information accurately and effectively to solve problems, manage goals and time, work independently and become students who can manage themselves. The

ability to be able to access, evaluate, use and manage information effectively and efficiently to solve problems independently is referred to as metacognitive (Trilling et al., 2010).

Metacognition is defined as thinking about thinking or cognition about one's cognition (Gama, 2004; Livingston, 1997; Pierce, 2003). Metacognitive relates to students' awareness of their thinking processes, organizing and re-checking their thinking processes in order to determine certain learning strategies appropriately (Flavell, 1979; Nur, 1998). There are three dimensions of the metacognitive thinking process,

## How to Cite:

Aliyah, H., Erman, Hartono, D., & Mubarak, H. (2023). Explore Students' Metacognitive Thinking Process in Solving Compound Polarity Problems Based on The Level of Academic Ability. *Jurnal Penelitian Pendidikan IPA*, 9(11), 9332-9340. <https://doi.org/10.29303/jppipa.v9i11.4293>

which consists of planning, monitoring, and reflection (Hoy, 2005; Jacobs et al., 1987; Moshman, 1995; Suratno, 2010). Planning includes determining how much time to give a task, what strategy to use, how to start, what resources to gather, what to follow, what to do, what to give your full attention to, and so on. Monitoring (monitoring) is self-awareness about "How do I do?". Monitoring requires asking, "Does this make sense? Can I finish it quickly? Have I studied enough?". Evaluation (evaluation) involves an assessment of the process and the end result of thinking and learning. Questions are required of the evaluation process, such as, "Should I change strategy? Is this paper finished?" (Hoy, 2005).

It is important to know the metacognitive of a person because knowledge of his cognitive process can help one in choosing the right strategy for solving problems (Lauren, 2009). Metacognitive plays an important role in the success of learning, so studying metacognitive activities is important to find out how students are able to learn and apply their learning strategies so that the desired learning achievement is achieved. The use of metacognitive skills will help students to overcome mistakes or deficiencies made by students because metacognitive acts as a regulator and controller of cognitive processes in learning and thinking so that learning and thinking is done more effectively and efficiently (Livingston, 1997). The determination of strategies used in solving problems aims to find the relationships between data and unknowns, so that the right problem solving will be found (Polya, 1973). Metacognitive skills are related to students' ability in problem solving, students who have metacognitive skills can identify problems well, determine the information and data to solve problems, determine methods and make careful decisions in problem solving (Güner et al., 2021).

Many research results show that metacognitive plays an important role in problem solving. Azizah et al. (2018) in their research shows that metacognitive skills are one of the higher order thinking skills needed in solving chemical problems. These metacognitive skills include: designing what to learn, monitoring the progress of learning outcomes, and assessing what is learned in problem solving. High metacognitive thinking skills for students are important for the success of the educational process (Azizah et al., 2021; Coşkun, 2018). High metacognitive thinking skills will be accompanied by thinking skills, reflective thinking skills to solve problems, and good decision making skills as well. Hollingworth et al. (2005) stated that when students are given the opportunity to apply their metacognitive strategies in solving problems, they can be more effective in solving problems. Güner et al. (2021) states that students with high metacognitive skills tend

to solve problems correctly by using the right strategies, mathematical notation and logical reasoning, while students with low metacognitive skills have difficulty understanding problems, choosing the right strategy, and finding correct answer.

Lee et al. (2006) and Malawau (2023) stated that metacognitive is the ability to know and monitor one's thinking power, so that a person's metacognitive processes will differ according to their abilities. This difference in ability allows for differences in metacognitive thinking processes in problem solving. Hoy (2005) and Asy'ari et al. (2022) stated that because people differ in their metacognitive knowledge and skills, they differ in how well and how quickly they learn. Aliyah et al. (2018) state that students with high academic abilities have more varied metacognitive thinking processes in solving problems compared to students with medium and low academic abilities. Aliyah (2016), Muhlisin et al. (2016) and Wardani (2017) which state that students with high abilities are able to solve problems with the stages: developing plans, monitoring implementation and evaluating actions, while students with medium and low abilities solve problems given through the stages: developing plans, a little monitoring implementation and a little evaluation of actions. Oudman et al. (2022) states that students with high academic abilities carry out self-monitoring and self-regulation more accurately and carefully than students with low abilities.

The polarity of a compound is part of a chemical aspect that is invisible or abstract, which means that concrete facts cannot be explained, but the truth can be proven by mathematical logic so that rationality can be formulated (BSNP, 2006). Solving abstract problems or questions often confuses students. Several studies have found students' errors or lack of understanding in solving chemical problems caused by errors in understanding chemical concepts, such as all bonds in polar molecules are polar, as well as all bonds in non-polar molecules are non-polar (Erman, 2017). This statement is inaccurate, molecules that have polar bond types can have non-polar molecular properties if their molecular shape is symmetrical. Thus, it is important to carry out in depth studies to analyzing students' metacognitive thinking processes based on academic ability level in chemistry learning, especially in solving compound polarity problems.

Based on the description above, this study aims to identify and describe students' metacognitive thinking processes in solving compound polarity problems based on academic ability level.

## Method

This research is a qualitative research, with the researcher as the main instrument. One hundred and eighty-four high school students in Indonesia who had obtained the material on Compound Polarity and took the Compound Polarity Problem Solving Test (CPPST) participated in the study. Based on field notes and scores in pursuing CPPST, students are classified into high,

middle and low academic ability groups. Then, six selected students from each group to be interviewed in depth about students' metacognitive thinking processes in solving compound polarity problems. Students' metacognitive thinking processes are identified based on indicators of the dimensions metacognitive activity which consist of the dimensions of planning, monitoring, and reflection (Setyadi, 2018) as shown in Table 1

**Table 1.** Dimensions of Metacognitive Activity

Dimensions of Metacognitive Activity					
Planning		Monitoring		Reflection	
P-1	Thinking/reading/writing what is known and what is not known	M-1	Reading repeat material until truly understood	R-1	Reflecting achievement of the objectives
P-2	Determining the objectives	M-2	Using rules such as: formulas, reaction equations, charts, graphs, etc	R-2	Reflecting on implementing more efficient strategies
P-3	Determining problem solving strategies	M-3	Monitoring something that is considered wrong, such as writing, drawings, molecular formulas/structures, etc	R-3	Analyzing the text/formula
P-4	Determining the results to be achieved	M-4	Monitoring carefully	R-4	Analyze the way decision making
P-5	Planning a representation (formula, reaction equation, etc.) to support understanding	M-5	Monitoring by arguing	R-5	Choosing intentionally the representation
		M-6	Revealing a lack of understanding	R-6	Recognizing the interaction between representations and ideas, one of which controls the theme
		M-7	Monitoring the planning deficiencies		
		M-8	Monitoring conformity between facts and objectives		

The data analysis technique uses summative content analysis which consists of three stages: (1) Identifying and counting words or content in the CPPST answer sheets and the results of interviews that describe students' metacognitive thinking processes. (2) Comparing the results of identification and calculations between one subject and another in the same group in solving on CPPST; and (3) Interpreting all data.

## Result and Discussion

### Group of Students with High Academic Ability

Based on the results of the analysis of the answer sheets and the results of interviews in working on CPPST, it was obtained that the students' metacognitive thinking processes at the planning stage consisted of five activities (P-1, P-2, P-3, P-4, and P-5), monitoring is six activities (M-1, M-2, M-3, M-4, M-5, and M-7) and reflection is one activity (R-1).

The planning stage can be seen from the students being able to express the information obtained after reading the questions; selecting important and unimportant information in solving problems such as

atomic number, bond type and molecular properties; define strategies to solve problems; determine the results or answers to be achieved. Example of interview results on the planning stage:

*Question : What information did you get after reading the problem?*

*Student : The problem tells about methane or CH<sub>4</sub> and SF<sub>4</sub>, accompanied by the polarity comparison table*

*Question : What information do you get from the polarity comparison table?*

*Student : Compounds SF<sub>4</sub> and CH<sub>4</sub>, both are composed of 5 atoms, the type of polar covalent bond, but the molecular properties are different, the SF<sub>4</sub> compound is polar while the CH<sub>4</sub> compound is non-polar.*

This shows that students think/read/write what they know and what they don't know from reading the questions. The answer sheet also shows students are able to sort out which information is important and which is not important to solve the problem. Students translate information from the polarity comparison table by writing "CH<sub>4</sub> has polar covalent bonds and non-polar

molecular properties, SF4 has polar covalent bonds and polar properties.

The monitoring stage can be seen from the fact that students need to read more than once to understand the questions. Students with high academic ability consistently read twice to really understand the problem. Other activities that can be seen from the monitoring stage are the existence of formula rules used to solve problems, such as rules for writing electron configurations using the Aufbau principle, and predicting Lewis structures and the shapes of CH4 and SF4 molecules using electron domain theory. Students also monitor for errors such as writing, drawing, or molecular structure by crossing out or using x-type on these errors. The CPPST answer sheet shows the existence of scribbles made by students during the process of working on the questions (Figure 1).

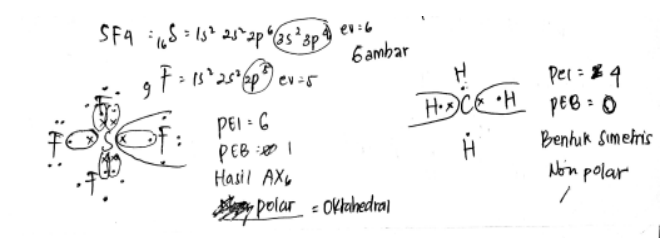


Figure 1. The CPPST answer sheet of student with high academic ability

The reflection stage can be seen from the brackets, underlines, arrows and circles used by students to mark something that is considered important in problem solving. The results of the interviews showed that students were confident about the steps or methods used in working on the questions and answers obtained. This shows that students reflect that the goal has been achieved or in other words a solution to the given problem has been obtained.

Group of Students with Midlle Academic Ability

The process of metacognitive thinking of students with midlle academic abilities in solving CPPST at the planning stage is five activities (P-1, P-2, P-3, P-4, and P-5), monitoring is four activities (M-1, M-2, M-5, and M-7), and reflection is one activity (R-1). The difference in the metacognitive thinking processes of students with high and middle academic ability is the monitoring stage.

Group of Students with Low Academic Ability

The process of metacognitive thinking of students with low academic ability in solving CPPST at the planning stage is three activities (P-1, P-3, and P-5), monitoring is one activity (M-2), and no reflecting.

In the planning stage, students express their confusion in understanding the questions. The results of

the interviews showed that students were unable to distinguish between important and unimportant information in solving problems. The answer sheet (Figure 2) shows students only writing down the atomic number and valence electrons of C and H atoms, as well as the Lewis structure of the CH4 compound. Students with low academic ability do not understand the purpose of the questions so that appropriate problem solving strategies are not obtained.

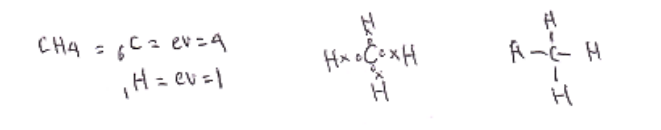


Figure 2. The CPPST answer sheet of student with low academic ability

In the monitoring stage, students are able to express well the methods or rules used in predicting CH4 compounds, but cannot determine the polarity of CH4 or SF4 compounds. In question number 2, students with low academic abilities also did not correctly calculate the difference in the electronegativity of BeCl2.

The reflection stage is not carried out by students with low academic ability. Students are not able to manage the time allotted properly in solving compound polarity questions so that the questions are not resolved perfectly. Students give reasons by arguing that the time allotted to work on the questions is insufficient. Based on the description above, the students' metacognitive thinking process in solving compound polarity based on academic ability level as shown in Table 2.

Table 2. Students' Metacognitive Thinking Process in Solving Compound Polarity Based on Academic Ability Level

Dimensions of Metacognitive Thinking Process	Academic Ability Level		
	High	Middle	Low
Planning	P-1	P-1	P-1
	P-2	P-2	
	P-3	P-3	P-3
	P-4	P-4	
	P-5	P-5	P-5
Monitoring	M-1	M-1	
	M-2	M-2	
	M-3		
	M-4		M-2
	M-5	M-5	
Reflection	M-7	M-7	
	R-1	R-1	

Planning Stage

The metacognitive thinking process of thinking/reading/writing what is known and what is not known (P-1) appears to be carried out by all subjects



in all domain questions. Students express what is understood from reading the questions, classify important and unimportant information in solving problems. This is in accordance with the opinion of Gok (2010) which states that the first step in solving the subject's problem is to be able to decide on important and necessary information to help solve the problem. Pulmones (2007) and Sari (2023) argues that metacognitive activities for the planning dimension in problem solving include thinking and writing down what is known and what is not known, and identifying where to find unknown information. Schoenfeld (Rysz, 2004) states that when someone reads a problem, he can indirectly know whether he understands or not what he reads.

The metacognitive thinking process of determining the objectives (P-2) shows that students know what to look for in order to solve problems. Students express what is asked and must be completed in the problem. This is in accordance with the views of Jacob and Paris (Jbeili, 2012) that the components of planning cognition regulation include setting goals, activating relevant resources, and selecting appropriate strategies. The activity of setting goals (P-2) carried out by the subject also shows that the subject understands the problem well. This is in accordance with the opinion of Polya (1973) which states that various things in problem solving, such as: what to look for, what are the requirements, what is being thought about and so on are included in the stage of understanding the problem.

The process of metacognitive thinking determines problem solving strategies (P-3) indicating that students know the knowledge that will be used to solve problems. Students involve their thinking processes to design strategies used in solving problems such as the use of electron configurations and Lewis structures. This is in accordance with the opinion of Anderson et al. (2010) who state that students who have knowledge, especially strategic knowledge, have various strategies that can be used to plan, monitor and manage their cognition. Polya (1973) is of the view that the determination of the strategy used in problem solving aims to find relationships between data and unknown things so as to facilitate the problem solving process.

The process of metacognitive thinking determines the results to be achieved (P-4) indicating that students know what results are to be achieved from problem solving. Students use prior knowledge to determine the results to be achieved. Students also carry out an analysis of important information that is known and problem-solving strategies that are arranged so that the results to be achieved are obtained. This supports the results of research conducted by Sugiarto et al. (2014) who found that metacognitive activities determine the

results to be achieved by the upper and middle groups in the problem solving stage.

The metacognitive thinking process plans a representation (formula, reaction equation, etc.) to support understanding (P-5). Students use Lewis structures to help simplify the problem solving process. Students analyse the Lewis structure to determine the shape of the molecule and determine the properties of the molecule. This is in accordance with the opinion of Gok (2010) in his research which states that in solving problems the subject must simplify the problem situation by drawing a diagram or sketch of a simple object and stating what you want to find mathematically for a certain quantity.

#### *Monitoring Stage*

The metacognitive thinking process of re-reading the material until it is fully understood (M-1) is carried out by students in the high and middle academic ability groups. Students read the material more than once to avoid mistakes in understanding the problem, find out important information used in problem solving and determine strategies that can be used in problem solving. This is in accordance with the opinion of Polya (1973) which states that understanding the problem well will facilitate the brain's thinking processes in solving activities, such as: what to look for, what are the requirements, what is being thought about and so on are included in the stage of understanding the problem. Gok (2010) states that the first step in solving a subject's problem is to be able to decide which information is important and needed to help solve the problem. The grouping of important and unimportant information in the problem requires reading the problem many times to understand the intent and purpose of the problem. This is also in accordance with the opinion of Oudman et al. (2022) that students with high academic abilities carry out self-monitoring and self-regulation more accurately and carefully than students with low abilities.

The process of metacognitive thinking uses rules such as: formulas, reaction equations, diagrams, graphs, etc. (M-2) is done by using rules or formulas to solve problems. Students write electron configurations according to Aufbau rules, describe Lewis structures and determine the shape of molecules. This is in accordance with the opinion of Anderson et al. (2010) who state that the ability to use procedures, knowledge of when to use the right procedures is an important condition for using them properly. Pulmones (2007) and Syahmani et al. (2023) that metacognitive manifestations of monitoring dimensions can be in the form of: using a dictionary to find difficult words, using pictures, making diagrams, making tables, writing small notes, and so on.

The process of metacognitive thinking monitoring something that is considered wrong, such as: writing, pictures, molecular formulas/structures, etc. (M-3) is carried out by high and middle academic groups. Answer sheets for female students tend to be clean from streaks and X-type marks. Jacob and Paris (Jbeili, 2012) state that monitoring of errors includes checking one's progress and selecting appropriate repair strategies when the previously chosen strategy is not working properly. This statement is supported by Anderson et al. (2010) who state that the existing strategies may not be suitable for all conditions, so students must know the conditions and tasks so that the strategies used are suitable and problem solving is obtained. This is in line with the opinion of Polya (1973) as an effort to find a way out of a difficulty, to achieve goals that cannot be completed immediately. This is very necessary when thinking about something that cannot be resolved immediately, especially in answering questions, a way out is needed so that the problem can be resolved to achieve a goal to be achieved.

The process of metacognitive thinking carefully monitors problem solving (M-4) is done by re-checking the answers before they are collected. Pulmones (2007) in his research stated that one of the monitoring activities is a manifestation of the dimensions of checking progress against goals or to-do lists. Woolfolk (Sugiarto, 2015) argues, monitoring activities are direct awareness of how we carry out a cognitive activity. This is in line with the opinion of Polya (1973) which states that students examine each solving step to show whether the steps taken are correct or whether the steps can be proven correct.

The process of metacognitive thinking monitors problem solving by arguing (M-5) is carried out by providing arguments that strengthen the answers obtained. Students express their arguments regarding the differences in the properties of the  $\text{CH}_4$  and  $\text{SF}_4$  molecules caused by different molecular shapes.  $\text{CH}_4$  has a symmetrical molecular shape so that the molecule is non-polar, while  $\text{SF}_4$  has an asymmetrical molecular shape so that the molecule is polar (Effendy, 2010).

The process of metacognitive thinking monitors any deficiencies in planning (M-7) indicating that students are aware of the lack of information provided in questions to solve problems. Students use another source, namely the periodic table of elements to find out the atomic number and location of the elements C, H, S, and F in the periodic table of elements. This is in accordance with the opinion of Pulmones (2007) that students who closely monitor problem solving know what information is needed in problem solving, use previous knowledge or other sources to support problem solving.

### *Reflection Stage*

The process of metacognitive thinking reflects on what concepts/goals have been achieved as there is an underline for the answer, writing the word "so", etc. (R-1) appears to be carried out by group subjects with high and middle academic ability. Students provide brackets and color stabilizer in the answers. Students also express their confidence in the methods used to solve problems and the answers they generate. This is in accordance with the findings of Pulmones (2007) that reflection carried out at the assessment stage can be in the form of re-checking what objectives were achieved, reflecting on which learning strategies were more efficient, assessing how learning strategies were applied to other contexts, and appreciating oneself after learning or completing task. Bound (Gama, 2004) states that assessment or reflection is an activity in which a person "recaptures his experience". A person who reflects or rethinks what he is thinking not only understands well what he knows, but is also able to make a conscious decision of his own to correct known errors. Sugiarto (2015) explains that the assessment activity includes making decisions about the resulting process based on the results of thinking and learning. This supports research conducted by Aliyah (2016) that reflection activity can be seen from the existence of an underline for answers that are only made by the high and medium groups, while the low group does not.

The low group did not carry out reflection activities because the questions to be completed were too long and there was not enough time to work on them. This is in accordance with the statement of Rambusch (2006) that to reflect on learning takes a lot of time. Lin (1994) strengthens this condition with his opinion which states that students and teachers have difficulty setting aside time to practice metacognitive reflection if the environment does not respect and does not support these activities. Lin further revealed that the activity of training metacognitive reflection and metacognitive strategies is part of daily activities to encourage the habit of doing reflection, not done at a certain time or for a certain task. Schunk (Pulmones, 2007) states that metacognitive self-assessment is deciding the quality of one's work. It is a process of assessing the quality of work performed based on evidence and specified criteria. To achieve the desired goals requires active involvement of students in the process and development of metacognitive skills, so that reflection activities are often not carried out because students are less able to manage time during learning as seen in the middle and low groups.

## Conclusion

Based on the results of the research and discussion above, it can be concluded that students' metacognitive thinking processes in solving compound polarity problems in terms of the level of academic ability include planning, monitoring, and reflection. Students with high academic abilities and are currently carrying out planning, monitoring, and reflection activities in solving the problem of compound polarity. Students with low academic abilities only carry out planning and monitoring activities. Metacognitive activities carried out by high groups are more varied and detailed than medium and low groups. Teachers need to train students metacognitively in solving problems and get used to applying metacognitive in each problem solving is given so that students are trained to solve problems systematically, carefully and thoroughly, and manage time well in order to obtain the expected learning achievement. Therefore, more in-depth research is needed that is able to explore students' metacognitive thinking processes in detail in terms of various other variables ; and further research on appropriate and efficient methods to improve the metacognitive skills of students in the medium and low groups because in this study, the researcher only revealed an overview of students' metacognitive processes based on the level of academic ability.

## Acknowledgments

The researchers would like to thank the principals, teachers, and students of high schools in Surabaya who have contributed and permitted the implementation of this research.

## Author Contributions

Himatul Aliyah: writing-original draft preparation, result, discussion, methodology, conclusion, review, and editing. Erman, Djoko Hartono, and Husni Mubarak: Analysis and proffreading.

## Funding

No external funding.

## Conflicts of Interest

The authors declare no conflict of interests regarding the publication of this paper.

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